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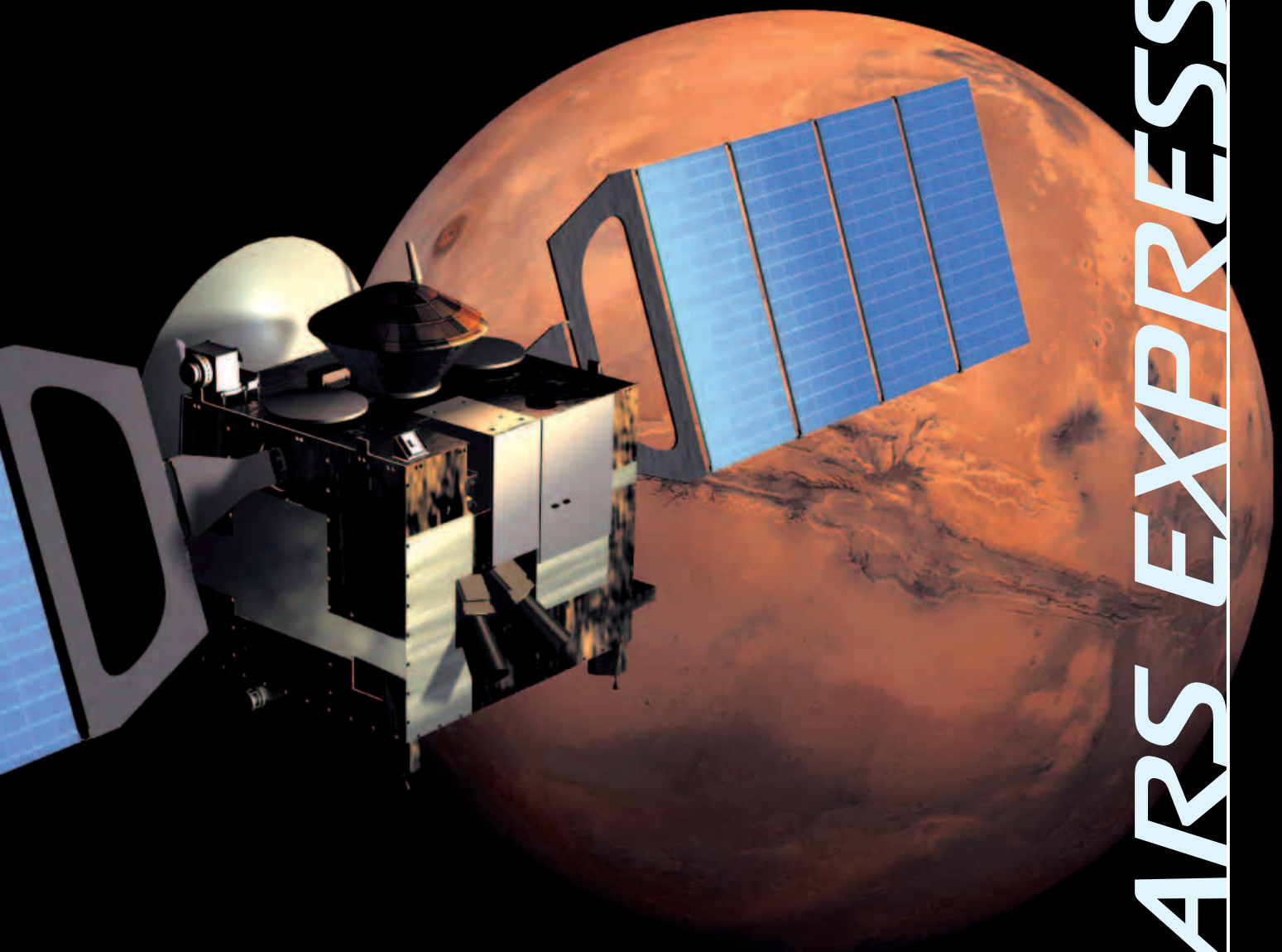
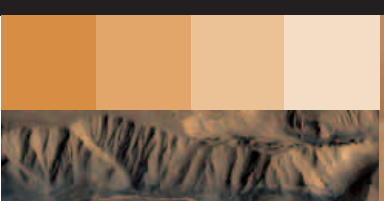
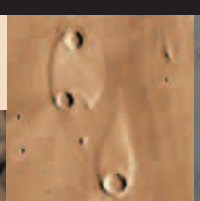
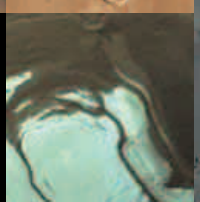
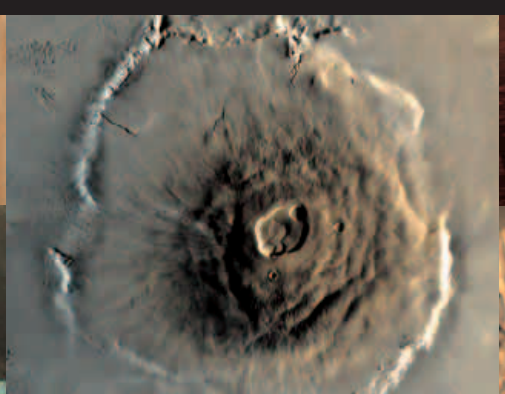
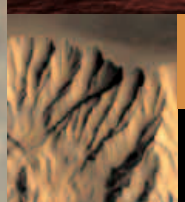
July 2001



MARS EXPRESS

Europe goes to Mars!



European Space Agency
Agence spatiale européenne

About ESA

The European Space Agency (ESA) was formed on 31 May 1975. It currently has 15 Member States: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada is also a partner in some of the ESA programmes.

The ESA Science Programme has launched a series of innovative and successful missions. Highlights of the programme include:

Cluster, which is a four spacecraft mission to investigate in unprecedented detail the interaction between the Sun and the Earth's magnetosphere

Giotto, which took the first close-up pictures of a comet nucleus (Halley) and completed flybys of Comets Halley and Grigg-Skjellerup.

Hipparcos, which fixed the positions of the stars far more accurately than ever before and changed astronomers' ideas about the scale of the Universe.

Hubble Space Telescope, a collaboration with NASA on the world's most important and successful orbital observatory.

Huygens, a probe to land on the mysterious surface of Saturn's largest moon, Titan, in 2004. Part of the international Cassini mission.

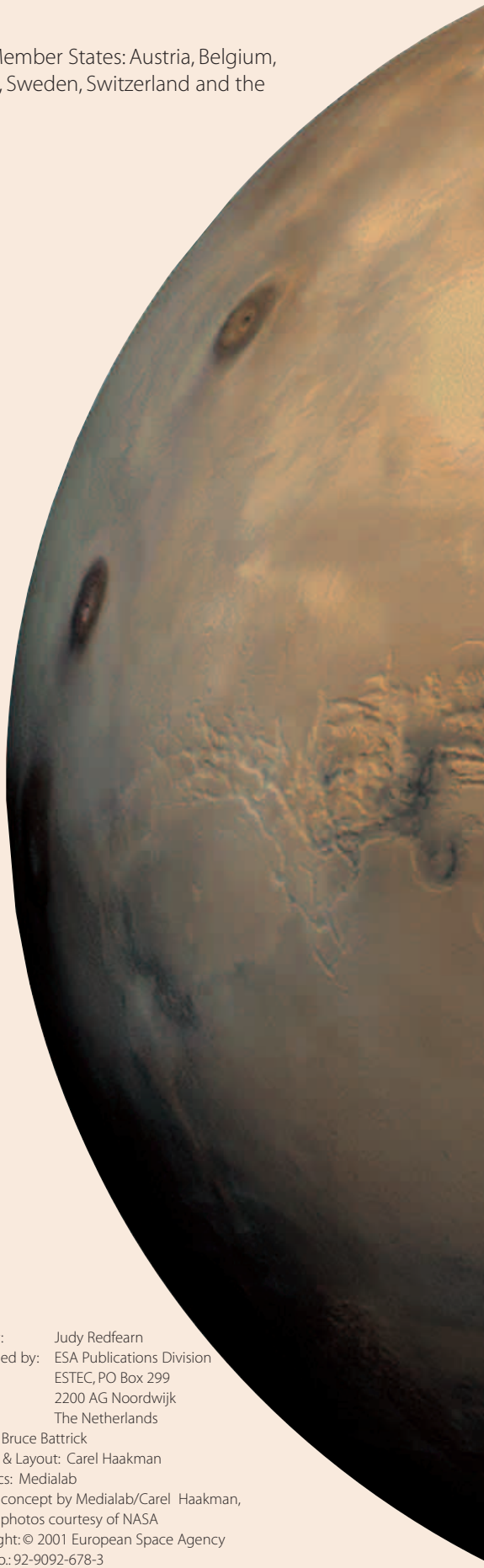
ISO, which studied cool gas clouds and planetary atmospheres. Everywhere it looked, it found water in surprising abundance.

IUE, the first space observatory ever launched, marked the real beginning of ultraviolet astronomy.

SOHO, which is providing new views of the Sun's atmosphere and interior, revealing solar tornadoes and the probable cause of the supersonic solar wind.

Ulysses, the first spacecraft to fly over the Sun's poles.

XMM-Newton, with its powerful mirrors, is helping to solve many cosmic mysteries of the violent X-ray Universe, from enigmatic black holes to the formation of galaxies.



For further information on the ESA Science Programme please contact the Science Programme Communication Service on (tel.) +31-71-5653223; (fax) +31-71-5654101

More information can also be obtained via the ESA Science Web Site at: http://sci.esa.int

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A European orbiter and lander mission to the Red Planet

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Courtesy of USGS/NASA

Europe reclaims a stake in

From the Greeks more than two thousand years ago to Eugene Antoniadi in the mid-1900s, Europeans have made many important observations of Mars with the naked eye and through Earth-bound telescopes. They have even contributed their fair share of speculation and fantasy about the planet in a fine tradition beginning in 1897 with the publication of *The War of the Worlds* by H G Wells in which hostile Martians invade Earth.

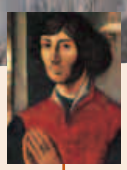
Europe, however, has never sent its own spacecraft to Mars – that is until now. The European Space Agency is building the Mars Express orbiter and its lander, Beagle 2, for launch to the Red Planet in 2003. The two vehicles will play key roles in an international exploration programme spanning the next two decades.

Research institutes throughout Europe are providing the instruments on board the orbiter. Some were first developed for the ill-fated Russian spacecraft, Mars '96. Now upgraded, they will provide remote sensing of the atmosphere, ground and up to 5 km below the surface, with a degree of accuracy never before achieved.

The information gleaned will help answer many outstanding questions about Mars. One concerns the fate of water that once flowed freely on the planet's surface early in its history; another is whether life ever evolved on the Red Planet.

Beagle 2 will be the first lander since NASA's two Viking probes in the 1970s to look specifically for evidence of past or present life. No other Mars probe planned so far is making exobiology so central to its mission.

Mars Express in orbit around Mars



1473 - 1543

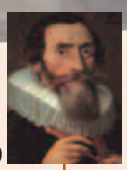
Nicolaus Copernicus

Described the motion of the planets, including Mars, around the Sun

1546 - 1601

Tycho Brahe

First to map accurately the movement of Mars across the sky



1561 - 1630

Johannes Kepler

Worked out the orbit of Mars

1564 - 1642

Galileo Galilei

First to observe Mars through a telescope

http://sci.esa.int/marsexpress

Mars exploration

"Mars Express is the first fully European mission to any planet. It is an exciting challenge for European technology."

Rudi Schmidt,
Mars Express Project Manager, ESA.

How the mission was named:	*Mars Express is so called because it will be built more quickly than any other comparable planetary mission. Beagle 2 is named after the ship in which Charles Darwin sailed when formulating his ideas about evolution.*
Prime contractor:	*Astrium, Toulouse, France, leading a consortium of 24 companies from 15 European countries and the USA*
Launch date:	*May/June 2003*
Launcher:	*Soyuz/Fregat, built by Starsem, the European/Russian launcher consortium*
Launch mass:	*1120 kg (including 113 kg orbiter payload and 60 kg lander)*
Lander:	*Beagle 2*
Orbiter instruments:	*High Resolution Stereo Camera (HRSC); Energetic Neutral Atoms Analyser (ASPERA); Planetary Fourier Spectrometer (PFS); Visible and Infrared Mineralogical Mapping Spectrometer (OMEGA); Sub-Surface Sounding Radar Altimeter (MARSIS); Mars Radio Science Experiment (MaRS); Ultraviolet and Infrared Mars Atmospheric Spectrometer (SPICAM);*
Operations:	*European Space Operations Centre (ESOC), Darmstadt, Germany*
Ground stations:	*ESA ground station in New Norcia, near Perth, Australia.*
Foreseen operational lifetime:	*One martian year (687 Earth days) is funded. The spacecraft is designed for a further martian year's operation.*
Arrival at Mars:	*December 2003*
Lander journey time from orbiter to surface:	*5 days*
Lander lifetime:	*180 martian days (about six Earth months)*
Lander mission management:	*University of Leicester, UK*

Illustration by Medialab ©ESA, 2001

1629-1695

Christiaan Huygens

First to observe a feature on Mars, the Syrtis Major

1625-1712

G. Domenico Cassini

First to observe the poles of Mars

1738-1822

William Herschel

First to measure the diameter of Mars

1835-1910

Giovanni Schiaparelli

Described 'canali' (channels), misinterpreted as canals on Mars

1870-1944

Eugene Antoniadi

Produced the most accurate map of Mars before the space age

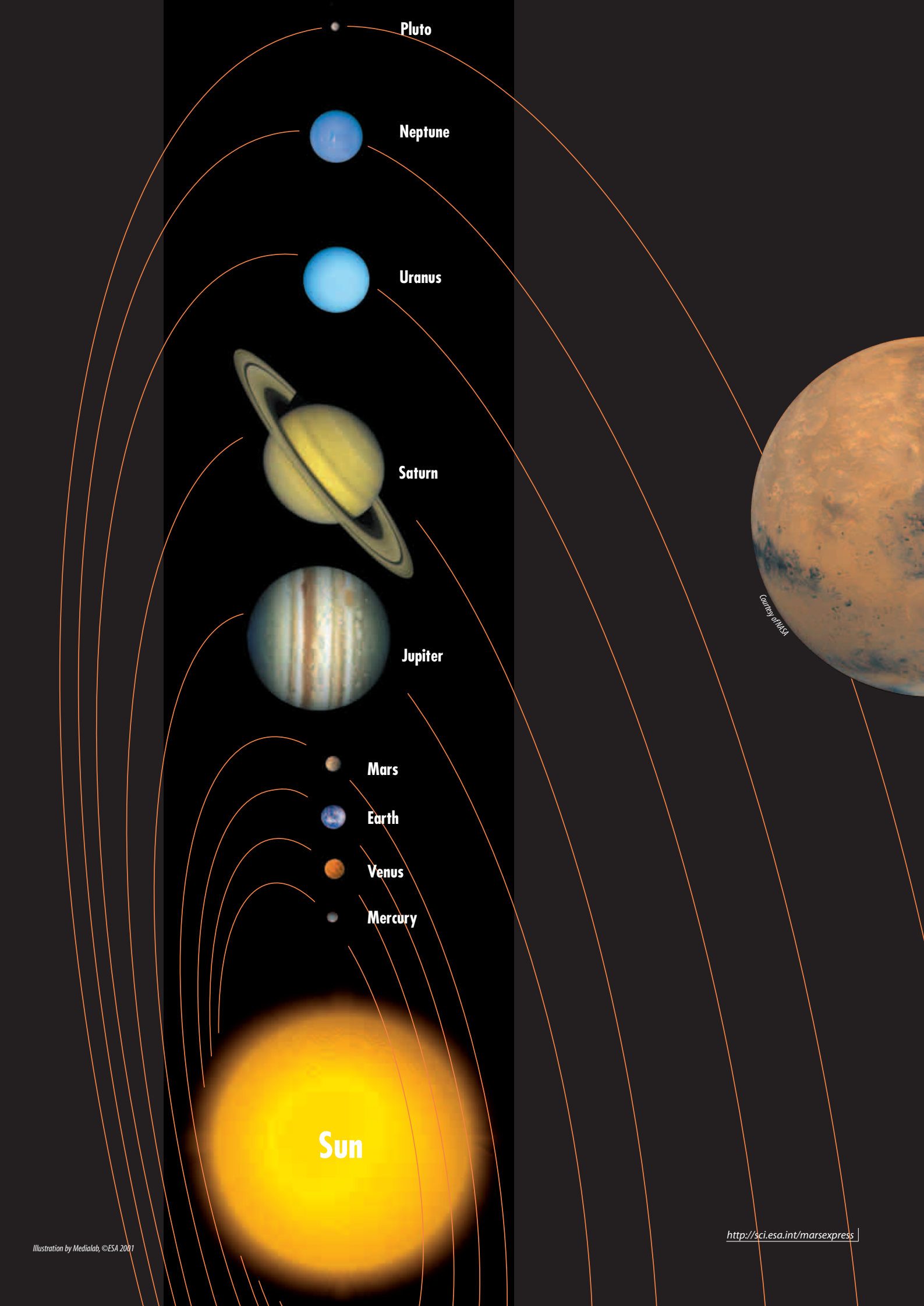
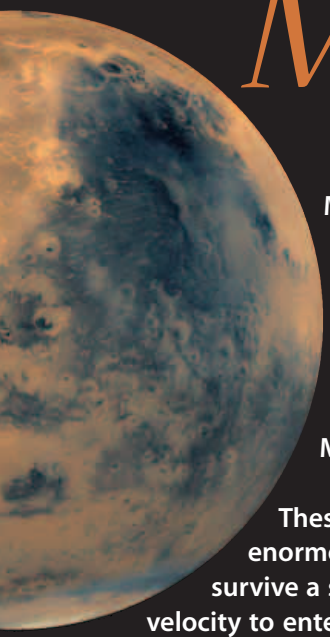


Illustration by Medialab, ©ESA 2001

http://sci.esa.int/marsexpress

Space age transforms our knowledge about

Mars



Mars has always held a fascination for us Earthlings. It is our immediate neighbour out from the Sun and the outermost of the hard, rocky terrestrial planets before the asteroid belt and the gas giants, such as Jupiter and Saturn. Since the first telescope observations of Mars in the early 1600s, we have suspected that it is more Earth-like than any other planet. Our desire to know it better has been driven by our need to learn more about our own planet and its place in the Solar System and by our fertile imaginations. Is Mars inhabited? Could it be a home for mankind in some distant future?

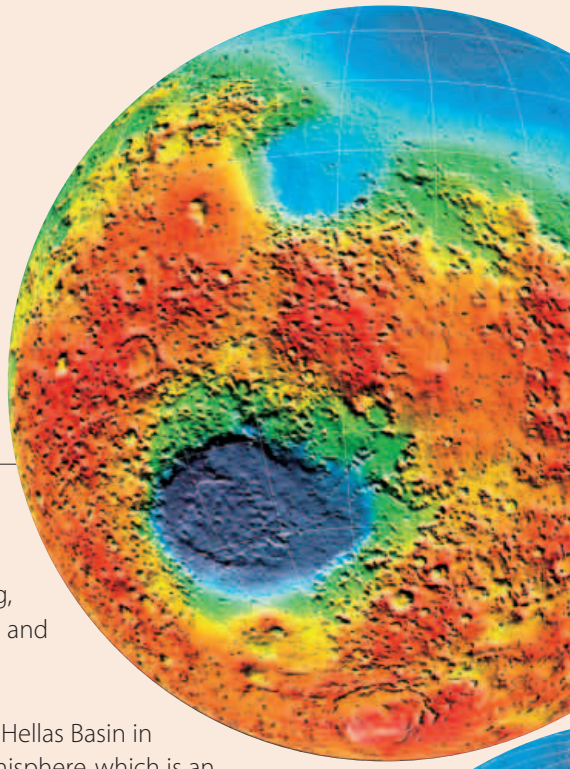
These and other questions have spurred scientists and engineers to meet the enormous challenge of sending a mission to Mars. A Mars-bound spacecraft must survive a six month journey, approach Mars from just the right angle and at the right velocity to enter orbit, and then work well enough to return valuable observations. Some missions have failed, but the successes have more than repaid the effort and risk.

It's hard to believe, for example, that just 40 years ago, some serious observers still thought thick vegetation grew on Mars. That myth was finally dispelled only in the late 1960s when NASA's Mariner 6 and 7 spacecraft flew past the planet and sent back images of a barren, but fascinating, landscape. Since then, our knowledge about Mars has grown dramatically with every subsequent visit by a successful space mission. Just two or three decades of space-based observation have produced more information and knowledge than earlier astronomers with Earth-bound telescopes could ever have imagined.

Facts about Mars

Orbit:	*227 940 000 km (1.52 AU) mean distance from the Sun*
Diameter:	*6794 km*
Martian day (sol) :	*24 hours 37 minutes and 22 seconds*
Martian year:	*669 Martian days (sols), 687 Earth days*
Average temperature:	*218 K (-55°C)*
Minimum temperature:	*140 K (-133°C) (winter pole)*
Maximum temperature:	*300 K (27 °C) (summer dayside)*
Surface area:	*144 x 10^6 km^2, about the same as the land area of Earth*
Atmospheric pressure at surface:	*6.35 mbar, i.e. less than one hundredth Earth's atmospheric pressure.*
Atmospheric composition:	*95.32% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.13% oxygen*
Moons:	*Phobos - diameter 22 km, orbit 5981 km from surface of Mars* *Deimos - diameter 12 km, orbit 20 062 km from surface of Mars*

A small planet with dramatic landscapes

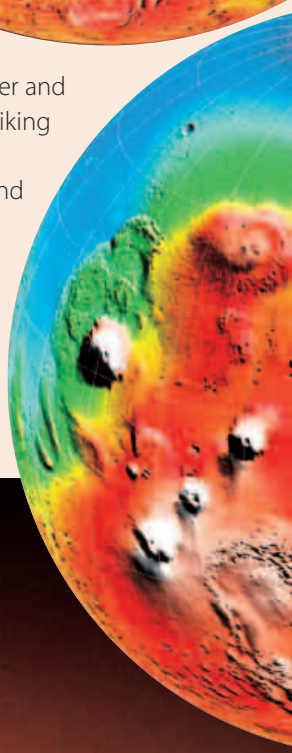


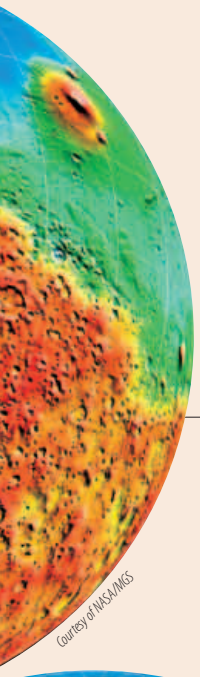
Although Mars is a small planet – its radius is just a little over half the Earth's – we now know that it boasts scenery on a scale that makes Mount Everest and the Grand Canyon seem unimpressive by comparison.

It has the highest volcano in the Solar System, Olympus Mons which rises 25 km above the surrounding plain: Mount Everest is only one third as high. Olympus Mons lies at the western edge of another gargantuan feature, the Tharsis dome, which is a 10 km high, 4000 km wide bulge in the martian surface.

Running from the eastern flanks of the rise, roughly along the equator, is Valles Marineris, a split in the martian crust 4000 km long (about a fifth of the martian circumference), up to 600 km wide and 7 km deep. The Grand Canyon is a mere 450 km long, up to 29 km wide and 1.6 km deep.

Then there is the Hellas Basin in the southern hemisphere, which is an enormous impact crater 2300 km in diameter and more than 9 km deep. But perhaps most striking of all is the general difference in height and surface roughness between the northern and southern hemispheres. The northern hemisphere is flat and young and on average 6 km lower than the rugged older highlands of the south.





Courtesy of NASA/MGS

Topographical map of Mars showing the height difference between the northern and southern hemispheres.

Courtesy of NASA

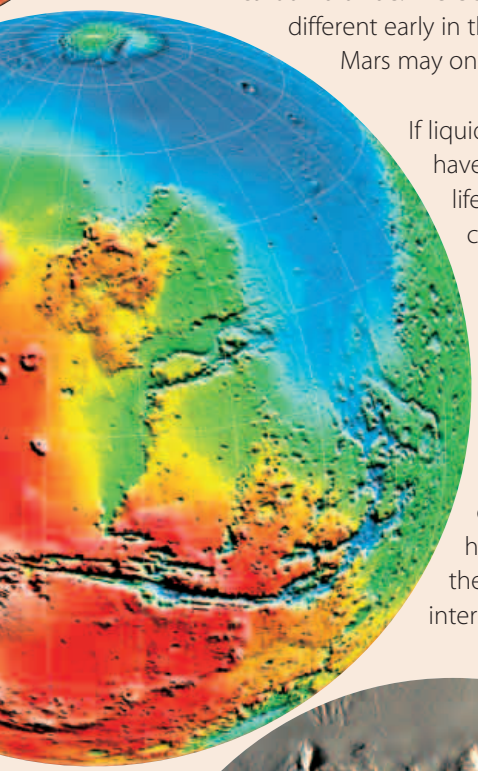
Controversy rages over whether this structure, found inside the martian meteorite ALH 84001, is a fossilised bacteria.

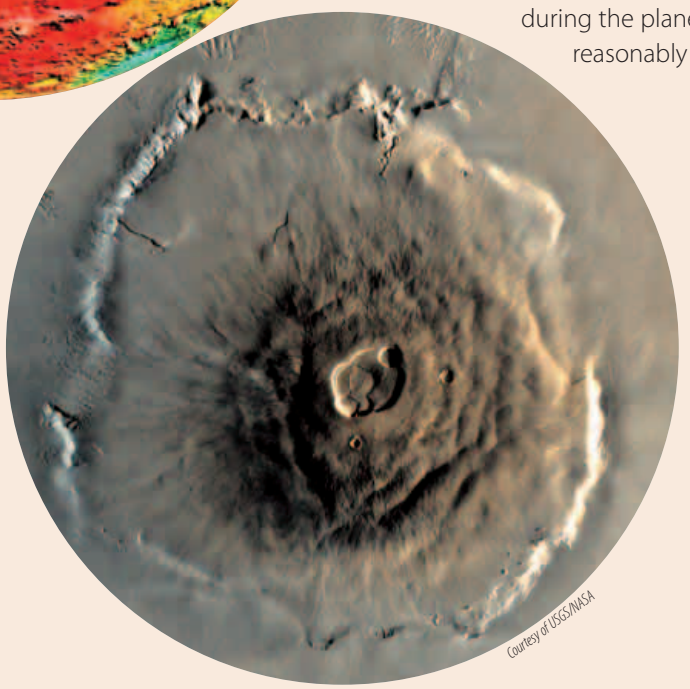
Water and life

Three decades of space exploration have also revealed that Mars is a cold, dry place with a thin atmosphere, consisting mainly of carbon dioxide. There's evidence, though, that conditions were very different early in the planet's history (3.8 billion years ago). Mars may once have been warm and wet.

If liquid water did flow on early Mars, could life have evolved there? The more we know about life on Earth, the more likely it seems that life could exist elsewhere. Over recent years, micro-organisms have turned up in the most inhospitable niches on Earth, where nobody previously thought anything could survive.

An energy source and water seem to be the only two essential prerequisites for life common to these niches. Water may once have flowed freely on Mars and, like the Earth, the planet receives sunlight and has its own internal energy source. So the odds on primitive life thriving for at least some time during the planet's history are reasonably good.





Courtesy of USGS/NASA

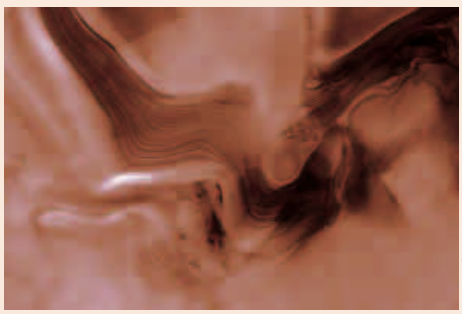
Olympus Mons. With its 25 km height, it is the highest volcano in the Solar System.

Courtesy of NASA

This image, taken by NASA's Mars Global Surveyor (MGS), may show evidence of recent underground water seepage.

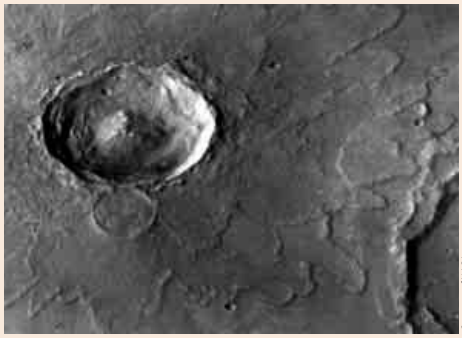
Courtesy of Calvin J. Hamilton

Frozen water and carbon dioxide over Mars' poles.



Courtesy of Calvin J. Hamilton

Could these layers, recently identified by MGS, be sediments deposited on ancient lake or ocean beds?



Courtesy of NASA

The splatter marks surrounding this impact crater suggest that the ground was water- or ice-logged when the impact occurred.

Artwork by Don Dixon, © 2001, courtesy of cosmographica.com

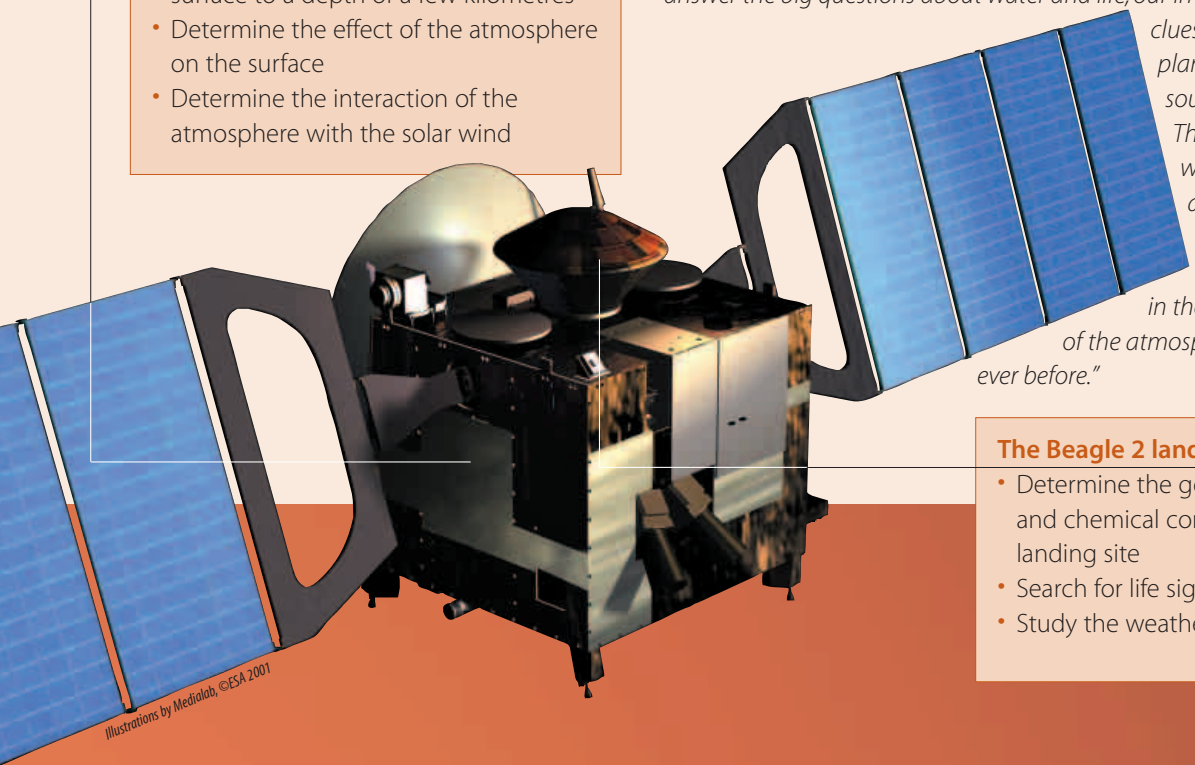
Mars Express: a planetary detective

The Orbiter will:

- Image the entire surface at high resolution (10 m/pixel) and selected areas at super resolution (2 m/pixel)
- Produce a map of the mineral composition of the surface at 100 m resolution
- Map the composition of the atmosphere and determine its global circulation
- Determine the structure of the sub-surface to a depth of a few kilometres
- Determine the effect of the atmosphere on the surface
- Determine the interaction of the atmosphere with the solar wind

Recent space missions have revealed a wealth of knowledge about Mars, but have also raised many questions. What forces, for example, created the spectacular features in the martian landscape? When did they cease? Or do some still act today? Was early Mars really warm and wet? If so, where did the water and atmosphere go? Did life evolve there? And is primitive life still thriving, perhaps associated with underground aquifers?

The Mars Express mission will help to answer these questions and many more by mapping the martian sub-surface, surface, atmosphere and ionosphere from orbit and by conducting observations and experiments on the surface. *"We are addressing a series of noble scientific objectives,"* says Agustin Chicarro, Mars Express Project Scientist at ESA. *"As well as helping to answer the big questions about water and life, our investigations will provide clues as to why the north of the planet is so smooth and the south so rugged, how the Tharsis and Elysium mounds were lifted up, and whether active volcanoes exist on Mars today. We should also find out about the minerals in the rocks and the composition of the atmosphere in greater detail than ever before."*



Illustrations by Medialab, ©ESA 2001

The Beagle 2 lander will:

- Determine the geology and the mineral and chemical composition of the landing site
- Search for life signatures (exobiology)
- Study the weather and climate

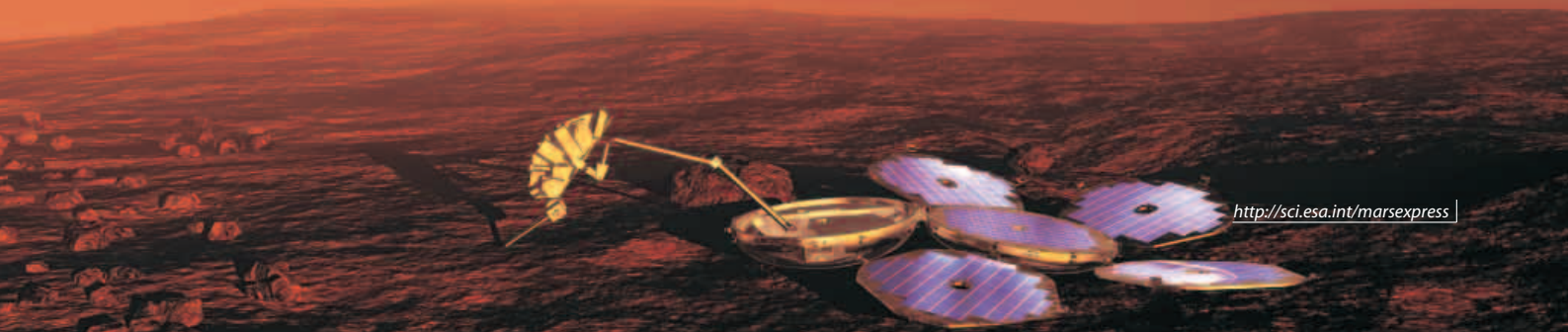
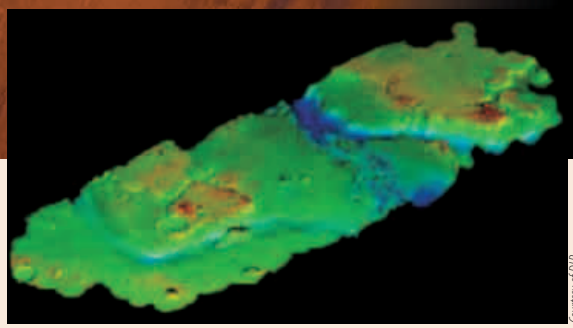


Illustration by Medialab, ©ESA 2001

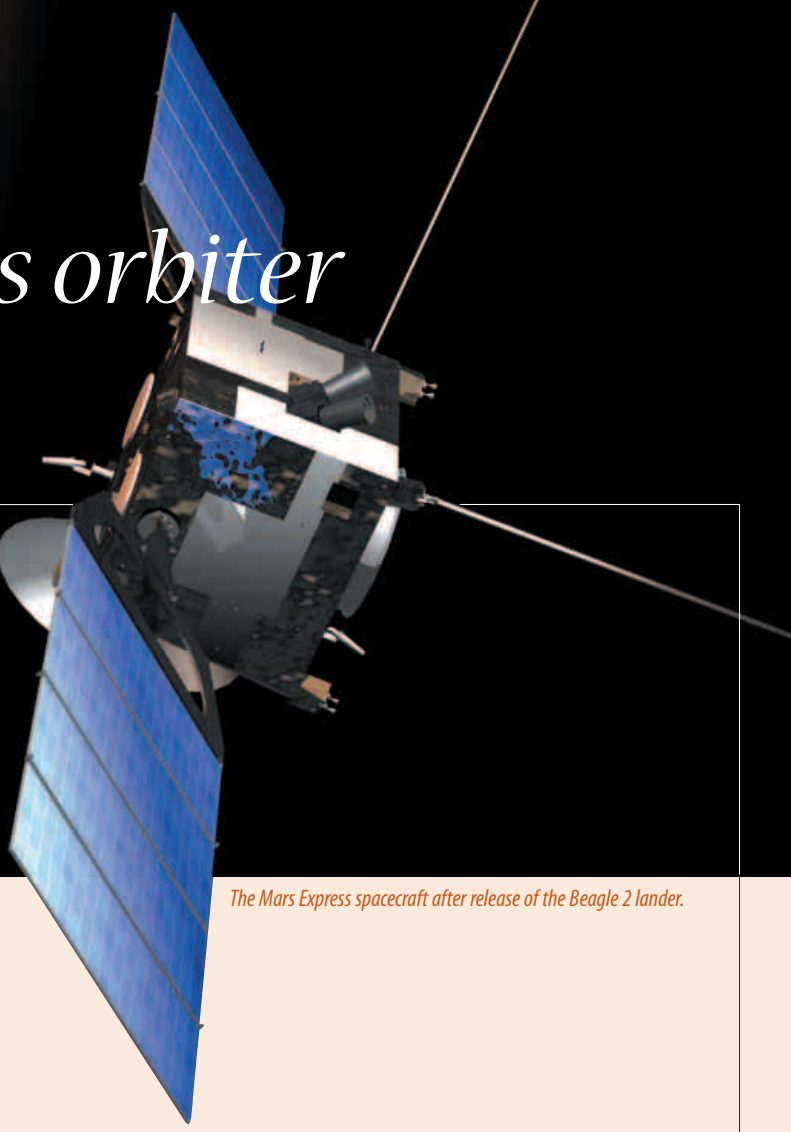
http://sci.esa.int/marsexpress

The Mars Express orbiter instruments

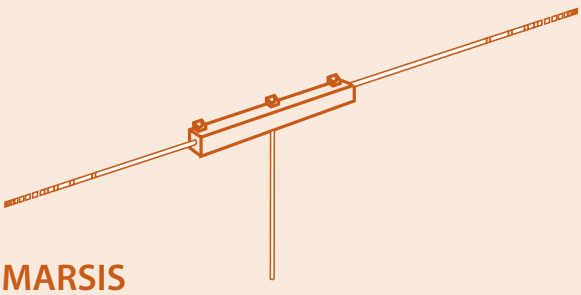


Courtesy of DLR

Digital terrain model of Kasei Valley, an outflow channel on Mars, showing the type of 3D imagery that the Mars Express camera (HRSC) will produce.



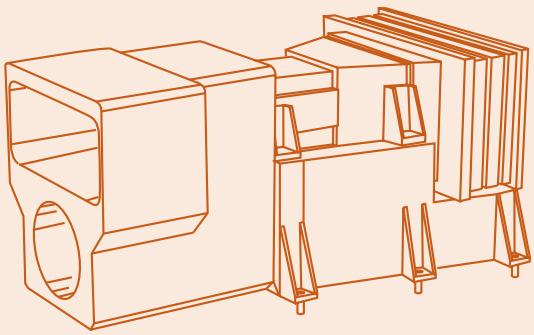
The Mars Express spacecraft after release of the Beagle 2 lander.



1 MARSIS

(Sub-Surface Sounding Radar Altimeter)

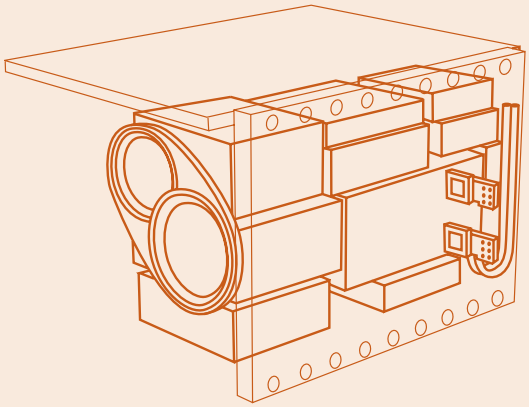
will map the sub-surface structure to a depth of a few kilometres. The instrument's 40 m long antenna will send low-frequency radio waves towards the planet, which will be reflected from any surface they encounter. For most, this will be the surface of Mars, but a significant fraction will travel through the crust to be reflected at sub-surface interfaces between layers of different material, including water or ice (see page 14 for more information on how Mars Express will help to solve the riddle of Mars' missing water). *"We should be able to measure the thickness of ice or permafrost, or determine whether there are layers of sediment sitting on top of other materials,"* says Giovanni Picardi, MARSIS Principal Investigator (PI) from Universita di Roma 'La Sapienza', Rome, Italy. MARSIS will also study the ionosphere, as this electrically-charged region of the upper atmosphere will reflect some radio waves.



2 HRSC

(High Resolution Stereo Camera)

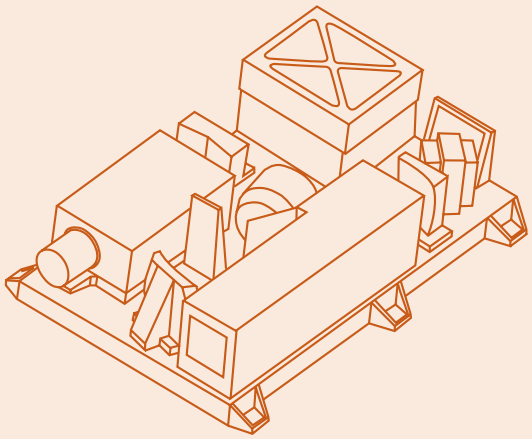
will image the entire planet in full colour, 3D and with a resolution of about 10 m. Selected areas will be imaged at 2 m resolution. One of the camera's greatest strengths will be the unprecedented pointing accuracy achieved by combining images at the two different resolutions. Another will be the 3D imaging, which will reveal the topography of Mars in full colour. *"As the 2 m resolution image is nested in a 10 m resolution swath, we will know precisely where we are looking. The 2 m resolution channel will allow us to just pick out the Beagle 2 lander on the surface,"* says Gerhard Neukum, HRSC Principal Investigator (PI) from DLR's Institut für Weltraumsensorik und Planetenerkundung, Berlin, Germany.



3 OMEGA

(Visible and Infrared Mineralogical Mapping Spectrometer)

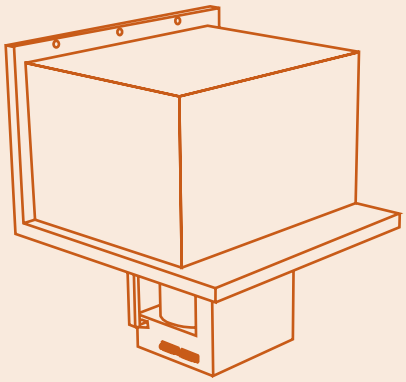
will build up a map of surface composition in 100 m squares. It will determine mineral composition from the visible and infrared light reflected from the planet's surface in the wavelength range 0.5 - 5.2 µm. As light reflected from the surface must pass through the atmosphere before entering the instrument, OMEGA will also measure aspects of atmospheric composition. *"We want to know the iron content of the surface, the water content of the rocks and clay minerals and the abundance of non-silicate materials such as carbonates and nitrates,"* says Jean-Pierre Bibring, OMEGA PI from the Institut d'Astrophysique Spatiale, Orsay, France.



4 SPICAM

(Ultraviolet and Infrared Atmospheric Spectrometer)

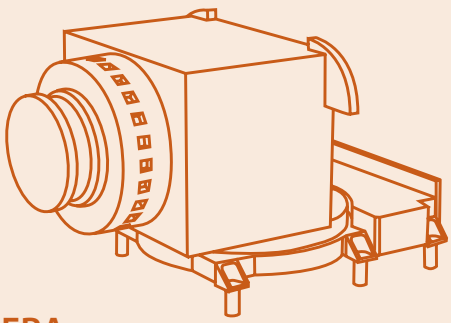
will determine the composition of the atmosphere from the wavelengths of light absorbed by the constituent gases. An ultraviolet (UV) sensor will measure ozone, which absorbs 250 nm light, and an infrared (IR) sensor will measure water vapour, which absorbs 1.38 µm light. *"Over the lifetime of the mission, we should be able to build up measurements of ozone and water vapour over the total surface of the planet for the different seasons,"* says Jean-Loup Bertaux, SPICAM PI from the Service d'Aeronomie du CNRS, Verrières-le-Buisson, France.



5 PFS

(Planetary Fourier Spectrometer)

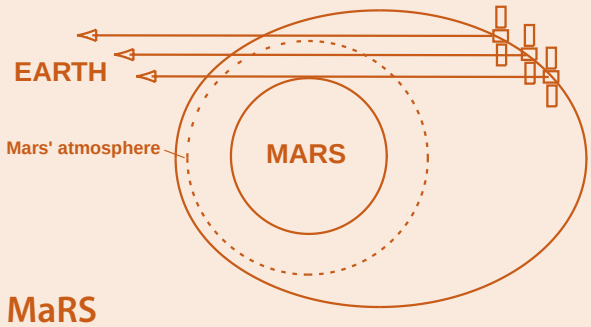
will determine the composition of the martian atmosphere from the wavelengths of sunlight (in the range 1.2 - 45 µm) absorbed by molecules in the atmosphere and from the infrared radiation they emit. In particular, it will measure the vertical pressure and temperature profile of carbon dioxide, which makes up 95% of the martian atmosphere, and look for minor constituents including water, carbon monoxide, methane and formaldehyde. *"We hope to get many, many measurements so that by taking the average of thousands we'll be able to see minor species,"* says Vittorio Formisano, PFS PI from CNR's Istituto di Fisica dello Spazio Interplanetario, Rome, Italy.



6 ASPERA

(Energetic Neutral Atoms Analyser)

will measure ions, electrons and energetic neutral atoms in the outer atmosphere to reveal the numbers of oxygen and hydrogen atoms (the constituents of water) interacting with the solar wind and the regions of such interaction. Constant bombardment by the stream of charged particles pouring out from the Sun is thought to be responsible for the loss of Mars' atmosphere. The planet no longer has a global magnetic field to deflect the solar wind, which is consequently free to interact unhindered with atoms of atmospheric gas and sweep them out into space. *"We will be able to see this plasma escaping the planet and so estimate how much atmosphere has been lost over billions of years,"* says Rickard Lundin, ASPERA PI from the Swedish Institute of Space Physics in Kiruna, Sweden.



7 MaRS

(Mars Radio Science Experiment)

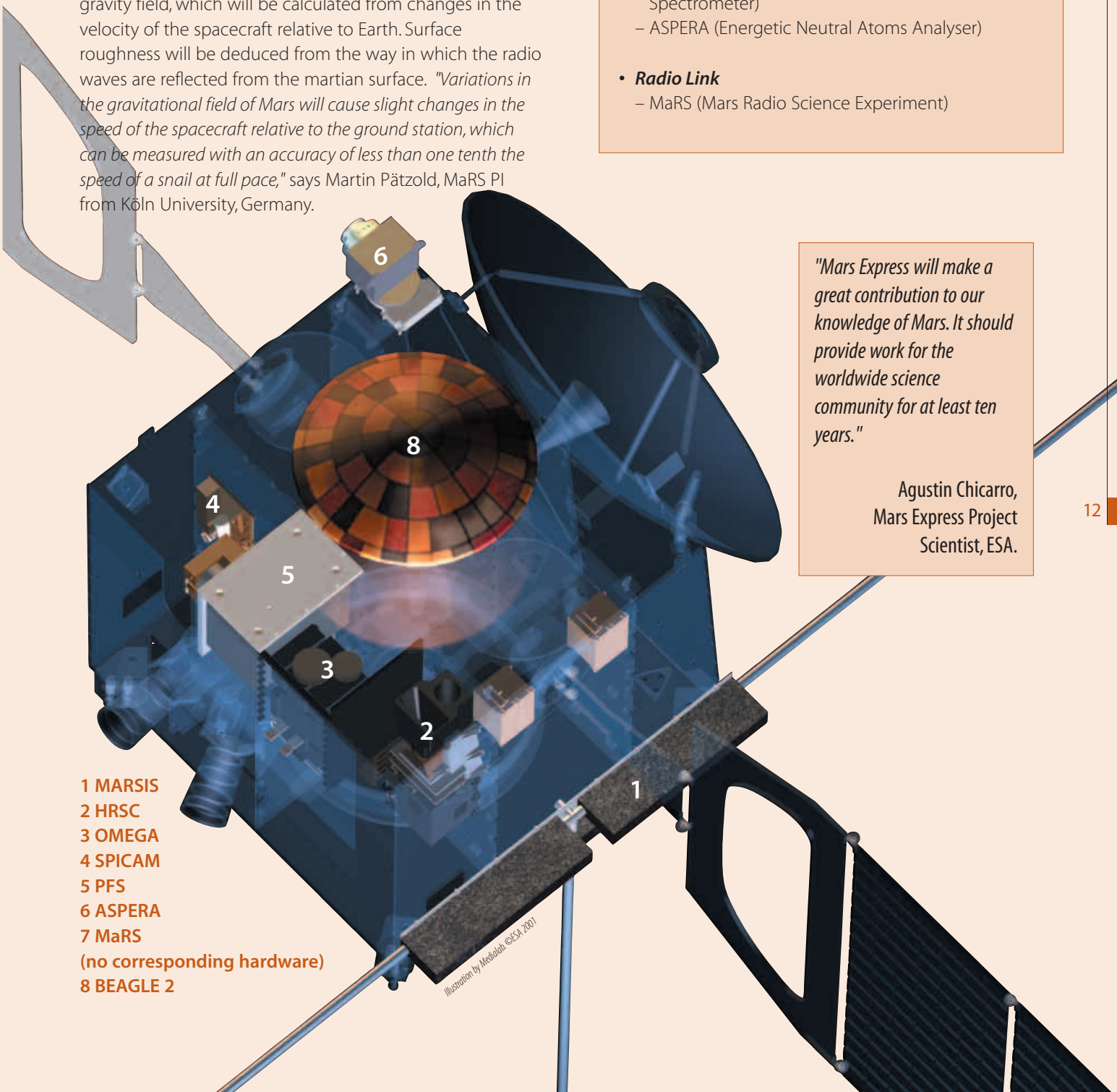
will use the radio signals that convey data and instructions between the spacecraft and Earth to probe the planet's ionosphere, atmosphere, surface and even interior. Information on the interior will be gleaned from the planet's gravity field, which will be calculated from changes in the velocity of the spacecraft relative to Earth. Surface roughness will be deduced from the way in which the radio waves are reflected from the martian surface. *"Variations in the gravitational field of Mars will cause slight changes in the speed of the spacecraft relative to the ground station, which can be measured with an accuracy of less than one tenth the speed of a snail at full pace,"* says Martin Pätzold, MaRS PI from Köln University, Germany.

Orbiter Scientific Payload

- ***Surface/Sub-surface Instruments***
  - HRSC (High Resolution Stereo Camera)
  - OMEGA (Visible and Infrared Mineralogical Mapping Spectrometer)
  - MARSIS (Sub-surface Sounding Radar Altimeter)
- ***Atmosphere/Ionosphere Instruments***
  - PFS (Planetary Fourier Spectrometer)
  - SPICAM (Ultraviolet and Infrared Atmospheric Spectrometer)
  - ASPERA (Energetic Neutral Atoms Analyser)
- ***Radio Link***
  - MaRS (Mars Radio Science Experiment)

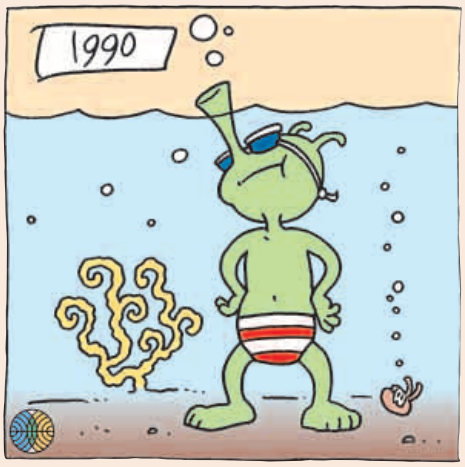
"Mars Express will make a great contribution to our knowledge of Mars. It should provide work for the worldwide science community for at least ten years."

Agustin Chicarro,
Mars Express Project
Scientist, ESA.

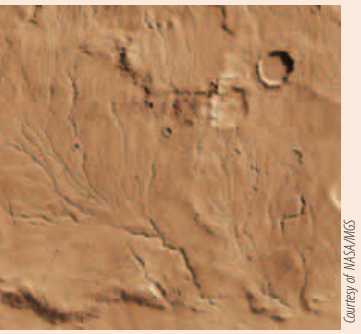


1 MARSIS
2 HRSC
3 OMEGA
4 SPICAM
5 PFS
6 ASPERA
7 MaRS
(no corresponding hardware)
8 BEAGLE 2

Was there water on early Mars?

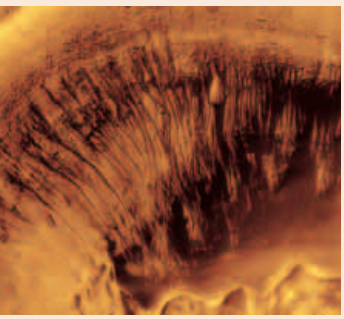


Perceptions have changed about how much water may have existed on early Mars. In 1970, scientists thought there may have been enough to support life - but only just. Over the next 30 years, their ideas about the planet have evolved gradually after each mission to Mars to include the presence of ever more water. If Mars really was as wet as many now think it could have been, early Martians would have been well advised to have their deep-sea diving gear to hand!



Courtesy of NASA/MGS

Valley networks, like these photographed by NASA's Viking mission, suggest that rivers once flowed on Mars.



Courtesy of NASA/MGS

In mid 2000 NASA's Mars Global Surveyor spacecraft reported what looked like evidence of water seeping up to the surface relatively recently.

Not only does Mars have the largest volcanoes and deepest canyons in the Solar System, it also shows evidence for the most catastrophic floods. Large channels carved by these floods drain into the northern plains, lending support for the existence of an ancient ocean over most of the northern hemisphere. Valley networks that criss-cross the southern highlands were probably formed by water. Also many craters, especially at high latitudes, are surrounded by fluidised ejecta resembling the ring of splattered debris around a stone dropped into soft mud. This suggests that there was underground water or ice in early times, and possibly more recently.

If water was largely responsible for these features, it has long since disappeared: most of the evidence is more than 3.8 billion years old. When Mars was a mere infant (like the Earth, the planet is 4.5 billion years old) much of its atmosphere and all of any surface water vanished. Today, atmospheric pressure at ground level is only about one hundredth that on Earth. So where did the atmospheric gases and water go and why? Each of the seven experiments on board the Mars Express orbiter will contribute towards the answer.

The water could have been lost to space, trapped underground, or both. Four of the instruments on Mars Express (ASPERA, SPICAM, PFS and MaRS) will observe the atmosphere and reveal processes by which water vapour and other atmospheric gases could have escaped into space. Two instruments (HRSC, OMEGA) will examine the surface and in the process add to knowledge about where water may once have existed and where it could still lie underground. One (MARSIS) will actually look for underground water and ice.

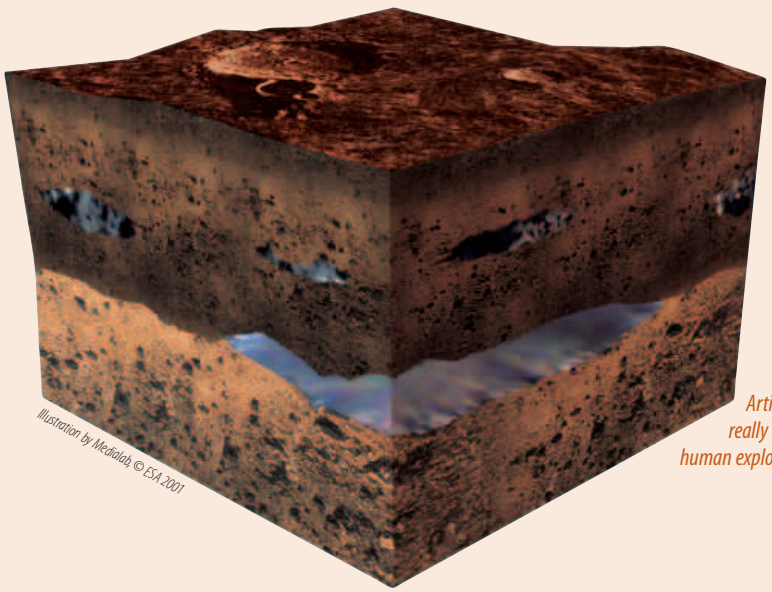
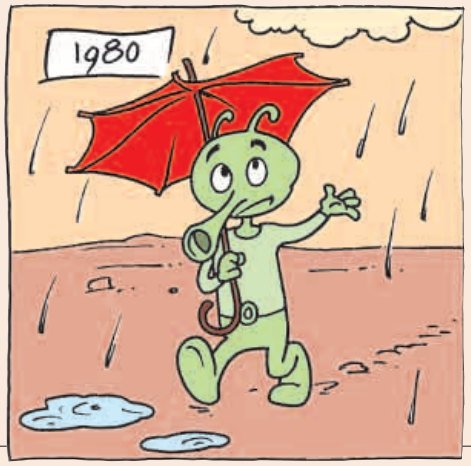


Illustration by Medialab, © ESA 2001

Artist's impression of water under the martian surface. If underground aquifers like that really do exist, Mars Express has a good chance of finding them. The implications for human exploration and eventual colonisation of the red planet would be far-reaching.

http://sci.esa.int/marsexpress



Signatures of life

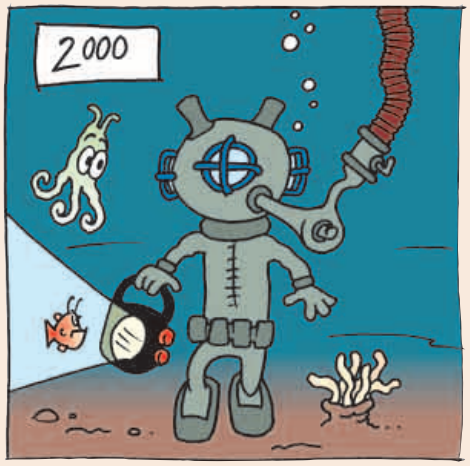


Illustration by Teemu Mäkinen. Courtesy of the Finnish Meteorological Institute

Where there's water, there could be life. *"Meteorites from Mars that have landed on Earth show clear evidence that conditions appropriate to life did exist on the planet, including in the recent past,"* says Colin Pillinger, Consortium Leader for the Beagle 2 lander at the Open University, Milton Keynes, UK. *"However, features in the meteorites which have been described as nanofossils are highly controversial. Unfortunately, we cannot be sure that organic matter found in the meteorites is the remnant of organisms that lived on Mars and not due to contamination on Earth. We need to repeat the experiments on rocks that never left the Red Planet."*

The Beagle 2 lander will look for signatures of life on Mars, whether long-dead or still-living, by measuring the ratio of two different types of carbon in the rocks. Biological processes on Earth favour the lighter isotope of carbon, carbon-12, over the heavier carbon-13. Hence, a high carbon-12 to carbon-13 ratio is taken as evidence of life and has been found in rocks up to 4 billion years old, even where geological processing has occurred. The hope is that the same occurred on Mars.

On Earth, some life that is still active produces another signature – methane. The simplest biological sources, such as those associated with peat bogs, rice fields and ruminant animals, continuously supply fresh gas to replace that destroyed by oxidation. Methane also has a very short lifetime on Mars because of the oxidising nature of the atmosphere, so its presence will indicate a replenishing source, which may be life, even if it is 1000 km away or buried beneath the surface.

The only previous landers to look directly for evidence of life on Mars were NASA's Vikings in 1976. However, Mars' harsh, oxidising atmosphere would almost certainly have destroyed any such evidence on the surface. Beagle 2 hopes to surmount this problem by using a "mole" to retrieve samples of soil from as much as 1.5 m below ground. It will also use a corer and grinder to expose the interior of rocks for study.

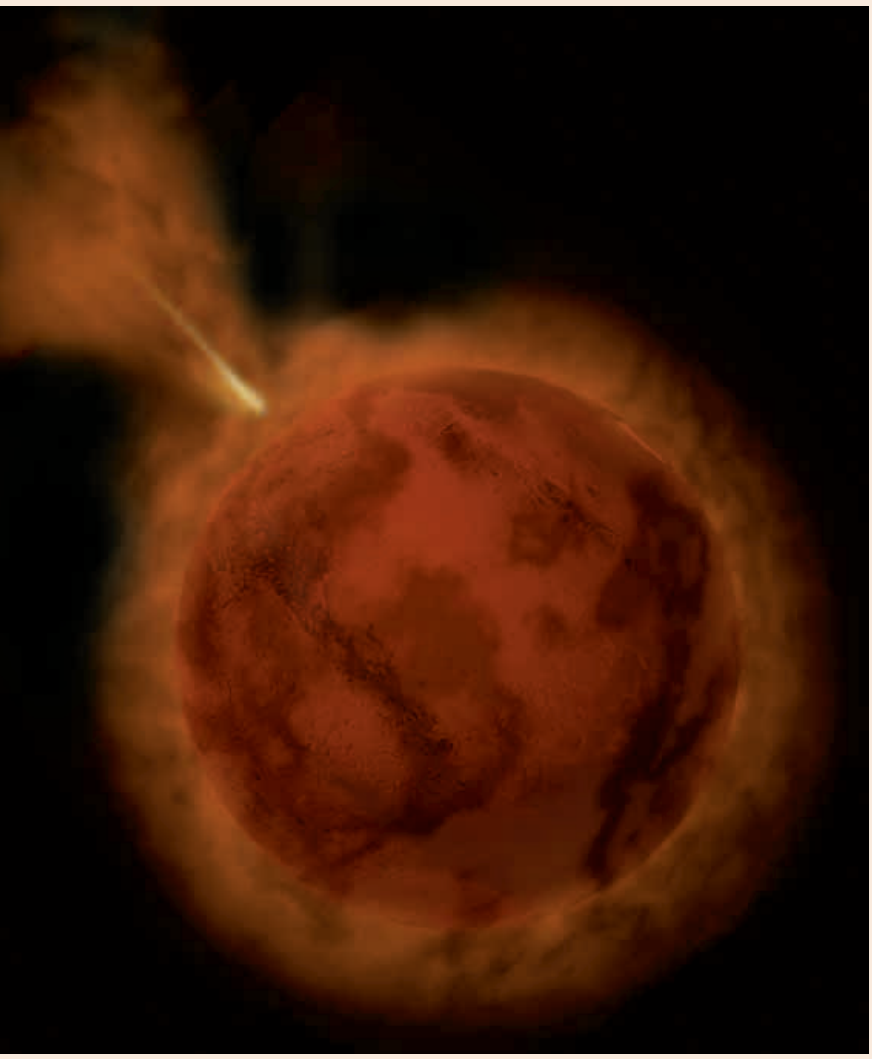


Illustration by Medialab, © ESA 2001

Mars may have lost much of its atmosphere during asteroid impacts early in its history.

Courtesy of the Natural History Museum.

Darwin's ship "Beagle".

The Beagle 2 lander

"HMS Beagle was the ship that took Charles Darwin on his voyage around the world in the 1830s and led to a quantum leap in our understanding about evolution of life on Earth. We hope that Beagle 2 will establish whether life began on Mars."

Colin Pillinger, Beagle 2 Consortium Leader, Open University, UK.

Beagle has a PAW

When folded up, the Beagle 2 lander resembles a very large pocket watch. This is the state in which it will pass the long journey to Mars. As soon as it comes to a halt on the martian surface, however, Beagle 2's outer casing will open to reveal the inner workings.

First, solar panels will unfold: they will catch sunlight to charge the batteries which will power the lander and its experiments throughout the mission. Next, a robotic arm will spring to life. Attached to the end of the arm will be Beagle's PAW (Payload Adjustable Workbench) where most of the experiments are situated. These include a pair of stereo cameras, a microscope, two types of spectrometer (Mössbauer and X-ray), and a torch to illuminate surfaces. The PAW also houses the corer/grinder and the mole, two devices for collecting rock and soil samples for analysis.

The robotic arm will stretch and rotate to give the two stereo cameras a good panoramic view of the landing site. After taking some shots, the cameras will take close-up images of nearby soil and rocks as potential candidates for further analysis. When a suitable rock has been chosen, the PAW will be rotated until the grinder is in position to grind away the weathered surface. The PAW can then be repositioned for the microscope or spectrometers to analyse the freshly exposed material.

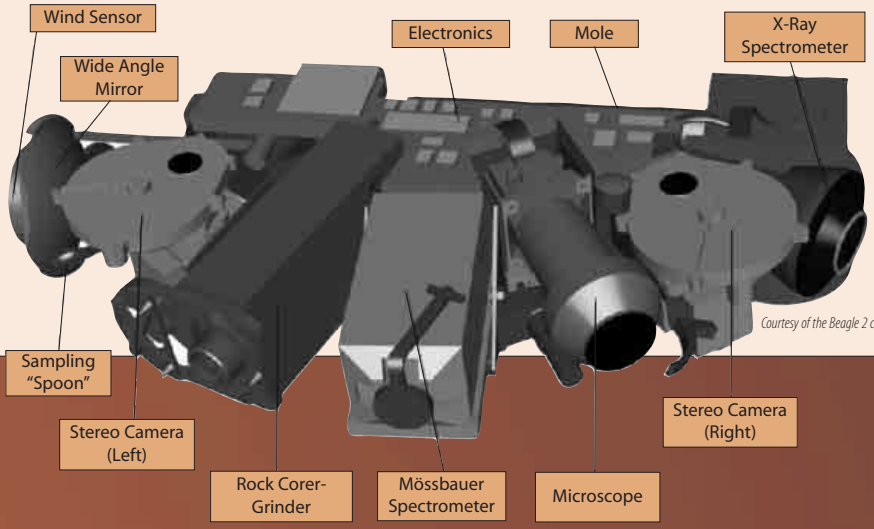
When a rock looks particularly interesting, a sample will be drilled out with the corer and taken to the Gas Analysis Package (GAP) inside the shell of the lander by means of the robotic arm. The mole carried on the back of the PAW will also collect soil samples and return them to the GAP.

The Gas Analysis Package

This is where investigations most relevant to detecting past or present life will be conducted. The instrument has twelve ovens in which rock or soil samples can be heated gradually in the presence of oxygen. The carbon dioxide generated at each temperature will be delivered to a mass spectrometer, which will measure its abundance and the ratio of carbon-12 to carbon-13. The mass spectrometer will also study other elements and look for methane in samples of atmosphere. The temperature at which the carbon dioxide is generated will reveal its nature, as different carbon-bearing materials combust at different temperatures.

The Environmental Sensors

A variety of tiny sensors scattered about the Beagle 2 lander will measure different aspects of the martian environment including: atmospheric pressure, air temperature and wind speed and direction; ultra-violet (UV) radiation; dust fall out and the density and pressure of the upper atmosphere during Beagle 2 's descent through the atmosphere.



The PAW instruments.

Courtesy of the Beagle 2 consortium.

Two Stereo Cameras

will provide digital pictures from which a 3D model of the area within reach of the robotic arm may be constructed. As the PAW cannot be operated in real time from Earth, this 3D model will be used to guide the instruments into position alongside target rocks and soil and to provide information on the geological setting of the landing site.

The Microscope

will pick out features a few thousandths of a millimetre across on rock surfaces exposed by the grinder. It will reveal the texture of the rock, which will help determine whether it is of sedimentary or volcanic origin.

The Mössbauer Spectrometer

will investigate the mineral composition of rocks by irradiating exposed rock surfaces and soil with gamma-rays emitted by an isotopic source (cobalt-57), and then measuring the spectrum of the gamma-rays reflected back. In particular, the nature of iron minerals in the pristine interior and weathered surface of rocks will be compared to determine the oxidising nature of the present atmosphere.

The X-ray Spectrometer

will measure the elemental composition of rocks by bombarding exposed rock surfaces with X-rays from four radioactive sources (two iron-55 and two cadmium-109). The rocks will emit lower energy X-rays characteristic of the elements present. Rock ages will be estimated using the property that the isotope potassium-40 decays to argon-40. The X-ray spectrometer will provide the potassium measurement and the GAP will measure argon trapped in rocks.

The Mole

will be able to crawl up to several metres across the surface at the rate of 1 cm every six seconds. Once it has reached a boulder, it will burrow underground to collect samples in a cavity in its tip. Alternatively, the PAW can be positioned such that the mole will burrow vertically underground to collect samples possibly 1.5 m below the surface.

The Corer/Grinder

consists of a drill bit which can either be moved over a surface to remove weathered material, or be positioned in one spot to drill a core of hopefully pristine sample.

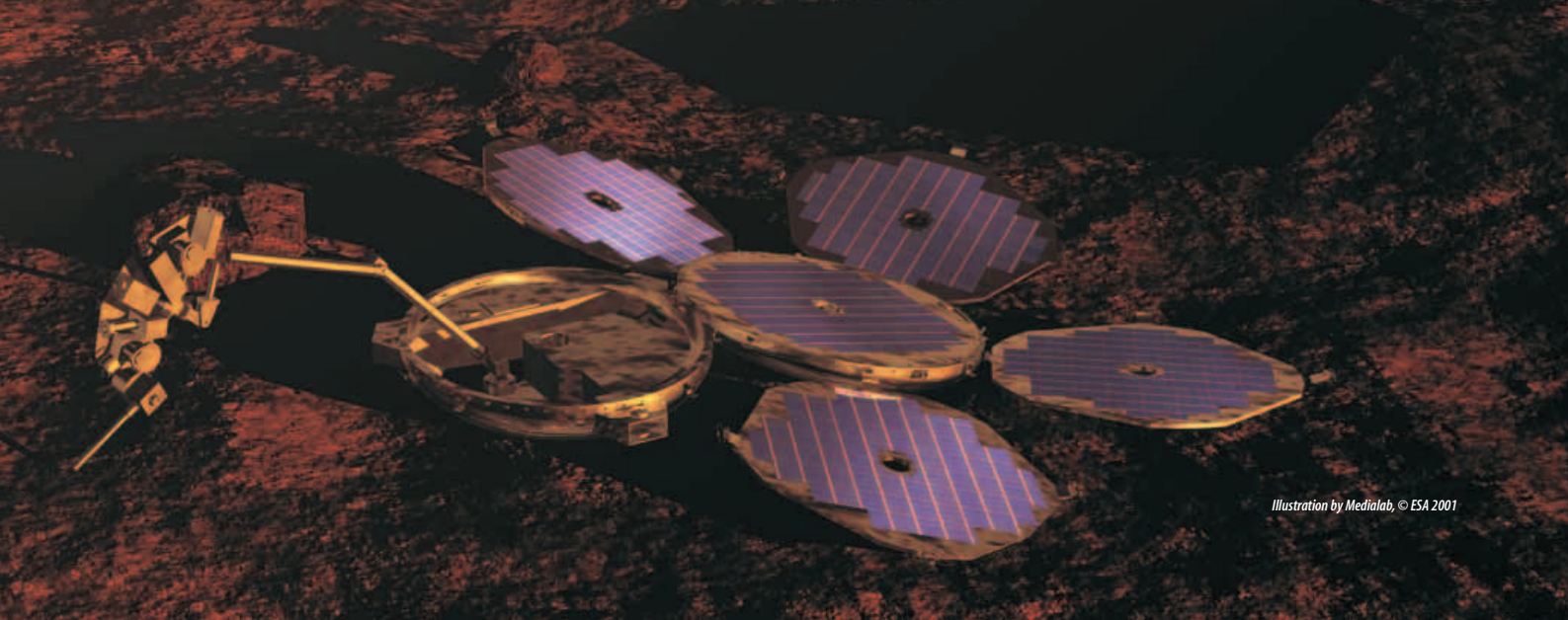


Illustration by Medialab, © ESA 2001

The mission

Mars Express will set off in 2003

Mars Express will leave Earth for Mars in late May or early June 2003 when the positions of the two planets make for the shortest possible route, a condition that occurs once every twenty-six months. The intrepid spacecraft will start its six-month journey from the Baikonur launch pad in Kazakhstan onboard a Russian Soyuz/Fregat launcher.

Once Mars Express has escaped the Earth and is on course for the Red Planet, it will begin the six-month interplanetary cruise at a velocity of 10 800 km/h relative to Earth. Five days before arrival in December 2003, Mars Express will eject the Beagle 2 lander, which will make its own way to the correct landing site on the surface. The orbiter will then manoeuvre into a highly elliptical capture orbit, from which it can move into its operational near-polar orbit.

"The mission is an exciting challenge," says Rudi Schmidt, Mars Express Project Manager. *"Mars Express will have a long cruise time in space followed by a very critical orbit injection. If we get the timing wrong, the spacecraft could burn up in the atmosphere or miss Mars altogether – so we have to get it right."*

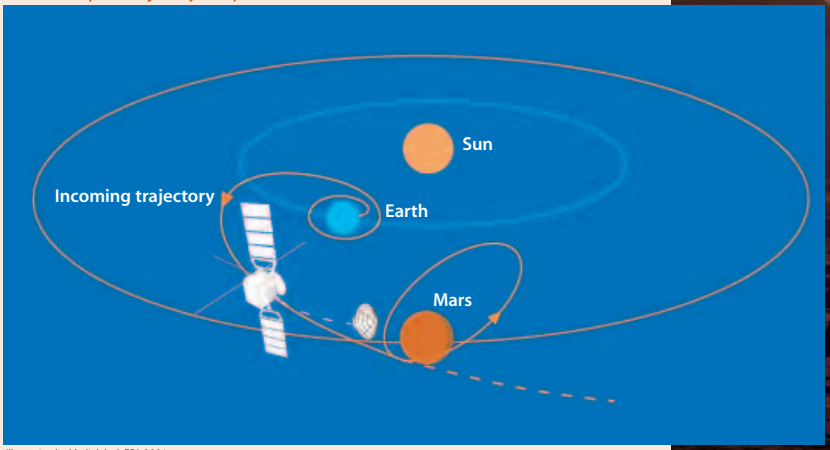
Mars Express will remain in orbit around the Red Planet for at least one martian year, 687 Earth days, which is the nominal mission lifetime. During this time, the point of the orbit closest to Mars (pericentre) will move around to give the scientific instruments coverage of the entire martian surface at all kinds of viewing angles.

Beagle 2 entry, descent and landing

Beagle 2 will descend to the surface, entering the atmosphere at more than 20 000 km/h. A heat-resistant front shield will protect it as friction with the upper atmosphere slows it down. When its speed has

	During first 440 days	After 440 days
Orbit inclination:	*86°*	*86°*
Apocentre: (furthest point from Mars)	*11 560 km*	*10 107 km*
Pericentre: (closest point to Mars)	*259 km*	*298 km*
Period:	*7.5 h*	*6.7 h*

The Mars Express trajectory and polar orbit.



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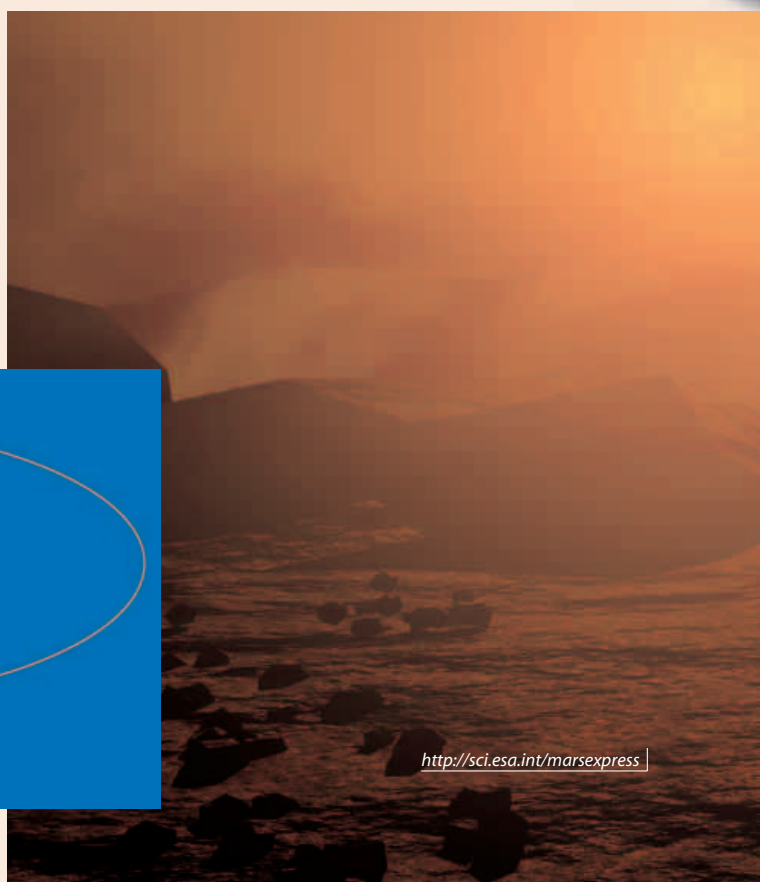


http://sci.esa.int/marsexpress

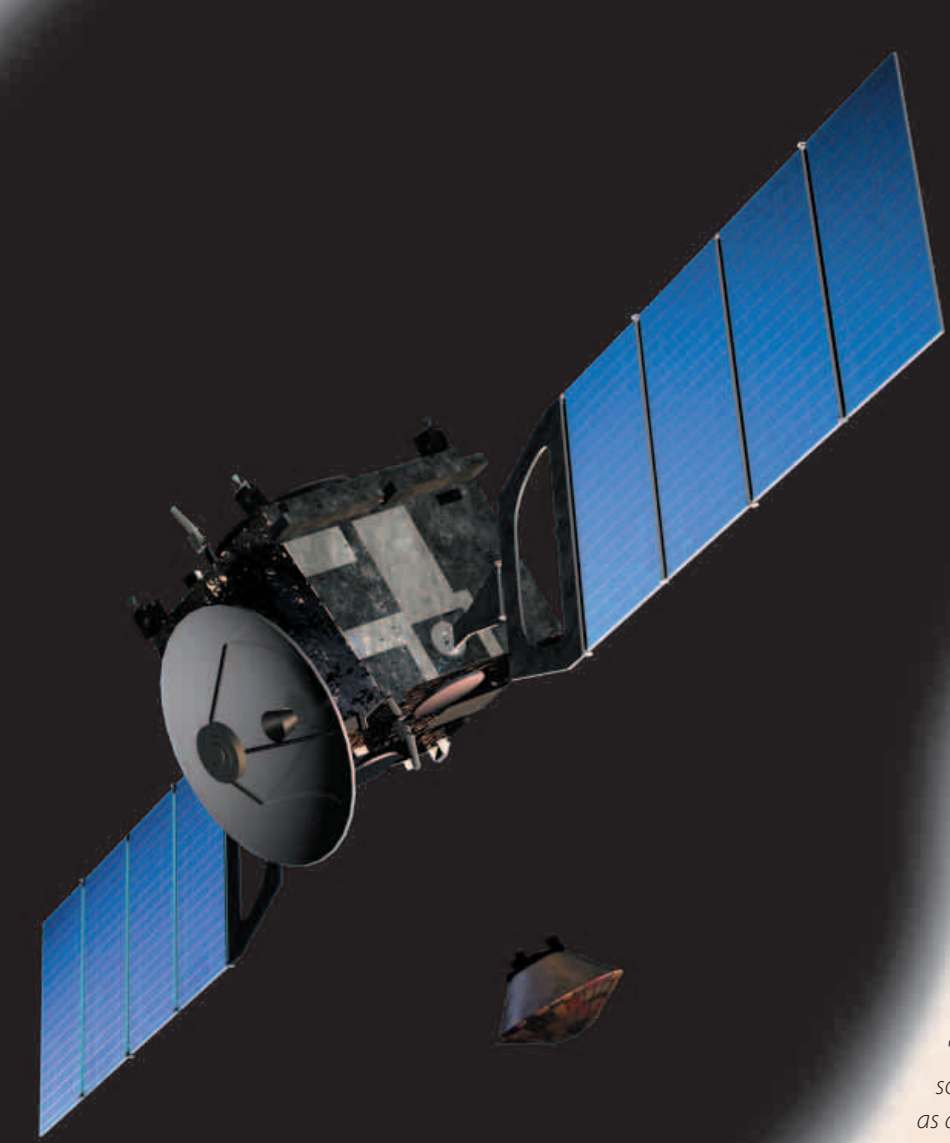


Illustration by Medialab, © ESA 2001

Beagle 2 leaving Mars Express (left) and entering the martian atmosphere (below).

fallen to about 1600 km/h, parachutes will deploy to slow it further. Finally, large gas-filled bags will inflate to protect it as it bounces to a halt on the chosen landing site.

As soon as it has come to a halt, the gas-filled bags will be released and ejected away from the lander, its clam-like outer casing will spring open, its solar panels will unfurl and its cameras will start to take in the view.

"Beagle 2 must accomplish its mission in just 180 sols (martian days, which are almost the same length as an Earth day)." The first few days will be spent running pre-programmed sequences, imaging the site and running the environmental sensors, preparing for when the lander will start doing very detailed rock and soil analysis," says Mark Sims, Beagle 2 Lander Manager from Leicester University, UK.

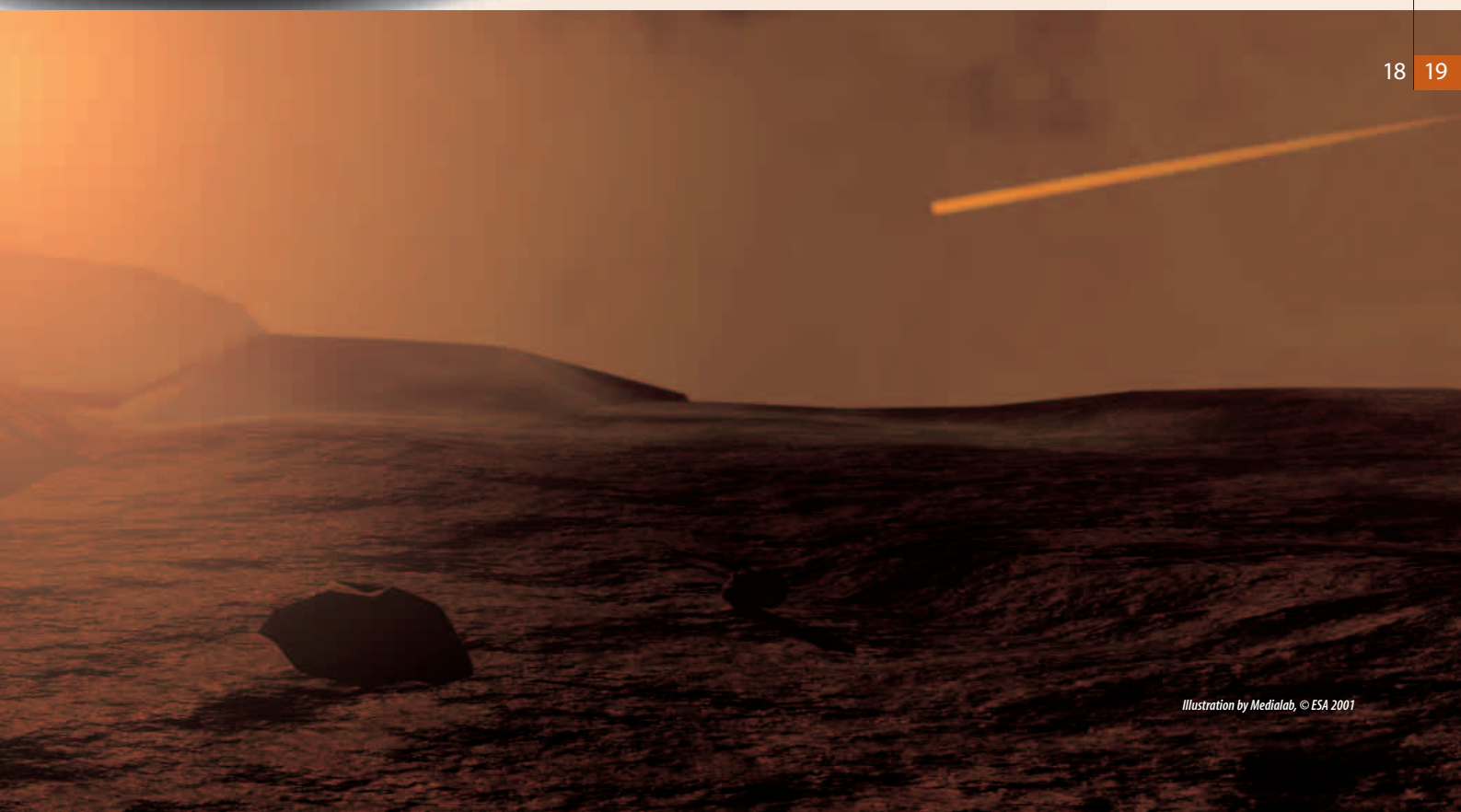


Illustration by Medialab, © ESA 2001

Beagle 2's heat resistant shield protects it from heat generated by friction with the martian atmosphere. Parachutes deploy to slow it down further, then gas-filled bags inflate to soften its landing.

Illustration by Medialab, © ESA 2001.

The Beagle 2 landing site.

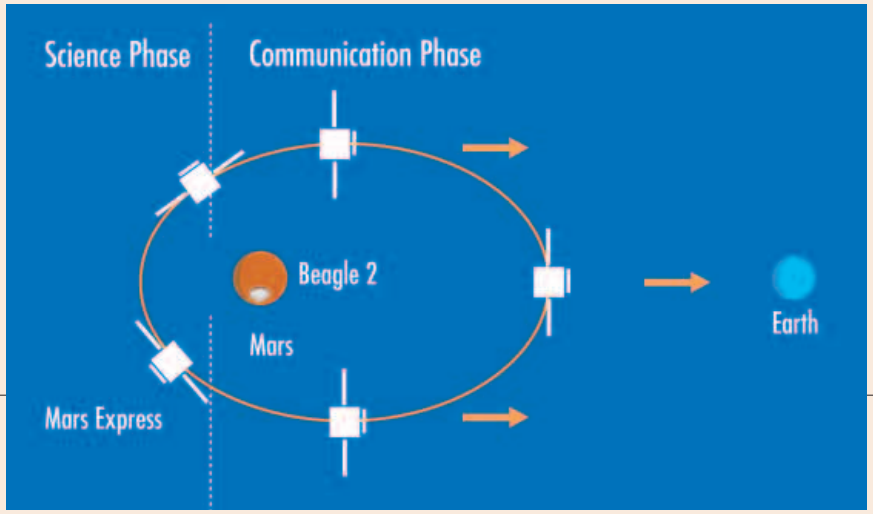
The landing site

Beagle 2 will land on Isidis Planitia, a large, flat sedimentary basin straddling the relatively young northern plains and ancient southern highlands, where traces of life could have been preserved. The landing site (10.6°N, 270°W) is at low latitude to minimise the amount of insulation (and hence mass) needed to protect the lander from the cold martian night.

The site is not too rocky to threaten a safe landing (but rocky enough to be interesting for the experiments), has few steep slopes down which the probe may have to bounce as it lands, and is not too dusty. Isidis Planitia is at a low enough elevation to provide sufficient depth of atmosphere to allow the parachutes to brake the lander's descent.

http://sci.esa.int/marsexpress

Illustration by Medialab, © ESA 2001



The Mars Express science and communication phases with the ground station on Earth.

Illustration by Medialab, © ESA 2001

Communications and spacecraft operations

During each orbit, Mars Express will spend some time turned towards the planet for instrument observations and some time turned towards Earth for communications with ground stations. The special UHF antenna will receive data from the Beagle 2 lander on the surface each time the spacecraft passes overhead.

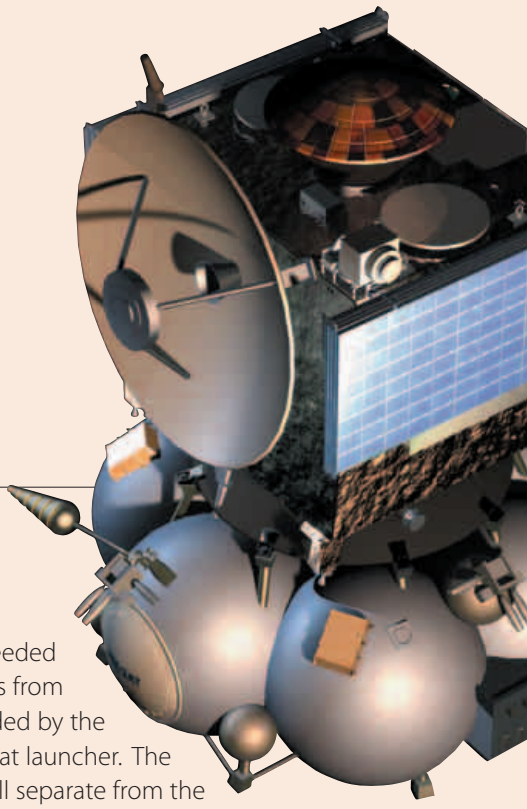
Data collected by Beagle 2 and the orbiter instruments will be transmitted to an ESA ground station at New Norcia near Perth, Western Australia at a rate of up to 230 kbps. Between 0.5 and 5 Gbits of scientific data will be downlinked from the spacecraft to Earth every day. From Perth they will be sent on to the European Space Operations Centre (ESOC) in Darmstadt, Germany, which will add spacecraft attitude and orbital data, and then re-transmit the data to the instrument Principal Investigators (PIs) for further processing and analysis. After about six months, the processed data will be sent to the European Space Research and Technology Centre (ESTEC) in Noordwijk, The Netherlands, for placing in a publicly available Mars Express science data archive.

Information on the health and position of the spacecraft will be included in a separate data stream. The Mars Express operations team at ESOC will use this information, together with the forthcoming operational needs of the instruments, to work out new commands to instruct the spacecraft how to behave over the coming days. The new commands will be sent to the spacecraft via the Perth ground station.

Ground control at the European Space Operations Centre in Darmstadt, Germany.

Photo: ESA.

The spacecraft



Spacecraft bus dimensions:	*1.5 x 1.8 x 1.4 m*
Thrust of main spacecraft engine:	*400 N*
Attitude thrusters:	*8 at 10 N each*
Propellant tanks volume:	*2 x 270 l = 540 l*
Pointing performance:	*0.15 deg*
Solar array area:	*11.42 m^2*
Lithium batteries:	*3 of 22.5 Ah each*

Propulsion

Most of the energy needed to propel Mars Express from Earth to Mars is provided by the four-stage Soyuz/Fregat launcher. The Fregat upper stage will separate from the spacecraft after placing it on a Mars-bound trajectory. The spacecraft uses its on-board means of propulsion solely for orbit corrections and to slow the spacecraft down for Mars orbit insertion. The main engine, on the underside of the spacecraft bus, is capable of delivering a force of 400 N, which will reduce the speed of the spacecraft by 2880 km/h in 30 minutes. (400 N is equivalent to the force needed on Earth to suspend a 40 kg weight above the ground). Eight attitude thrusters attached to the corners of the spacecraft bus can each deliver 10 N.

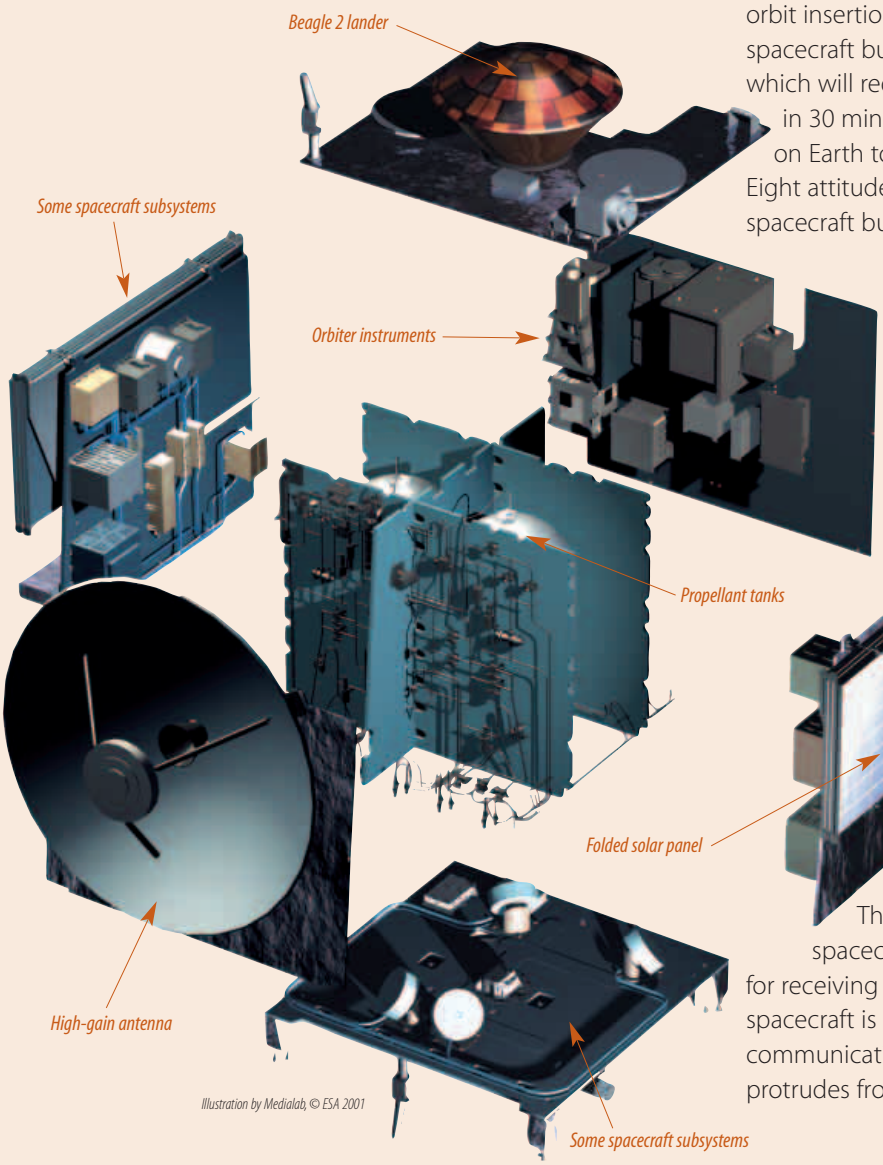


Illustration by Medialab, © ESA 2001

Electrical power

Electrical power is provided by the spacecraft's solar panels, which deploy shortly after launch. When Mars is at its maximum distance from the Sun (aphelion), the solar panels will still be capable of delivering 650 W, which is more than enough to meet the mission's maximum requirement of 500 W, equivalent to just five ordinary 100 W light bulbs! When the spacecraft's view of the Sun is obscured by Mars during a solar eclipse, a lithium-ion battery (67.5 Ah), previously charged up by the solar panels, will take over the power supply.

Communications

The circular dish attached to one face of the spacecraft bus is a 1.6 m-diameter high-gain antenna for receiving and transmitting radio signals when the spacecraft is a long way from Earth. When it is close to Earth, communication is via a 40 cm-long low-gain antenna, which protrudes from the spacecraft bus.

Mars Express mounted on the Fregat upper stage.

Illustration by Medialab, © ESA 2001.

The launcher

Data storage

As scientific data cannot be transmitted back to Earth as soon as it is collected, it will be stored on the spacecraft's computer until transmission is possible. The computer has 12 Gbits of solid-state mass memory.

Control

The on-board computers will control all aspects of the spacecraft's functioning, including switching instruments on and off, assessing the spacecraft's orientation in space, and issuing commands to change it.

Navigation

Three on-board systems will help Mars Express maintain a very precise pointing accuracy, which is essential if the spacecraft is to communicate with a 34 m dish on Earth up to 400 million km away. There are two star trackers, six laser gyros, and two coarse Sun sensors.

Thermal control

The spacecraft must provide a benign environment for the instruments and on-board equipment. Two instruments, PFS and OMEGA, have infrared detectors that need to be kept at very low temperatures (about -180°C). The sensors on the camera (HRSC) also need to be kept cool, but the rest of the instruments and on-board equipment function best at room temperature (10-20°C).

The spacecraft will be encapsulated in thermal blankets made from gold-plated aluminium-tin alloy, to keep the interior at 10-20°C .The instruments that need to be kept cold will be thermally insulated from the warm interior of the spacecraft and attached to radiators that lose heat to space, which is very cold (about -270°C).

The launcher

Starsem, a European-Russian company, is supplying the Soyuz/Fregat rocket that will launch Mars Express. The Soyuz rocket was first launched in November 1963 and has since flown more than 1500 times with a 98% success rate. It usually has three stages, but a fourth stage is added for particularly demanding launches. In the case of Mars Express, this is the Fregat.

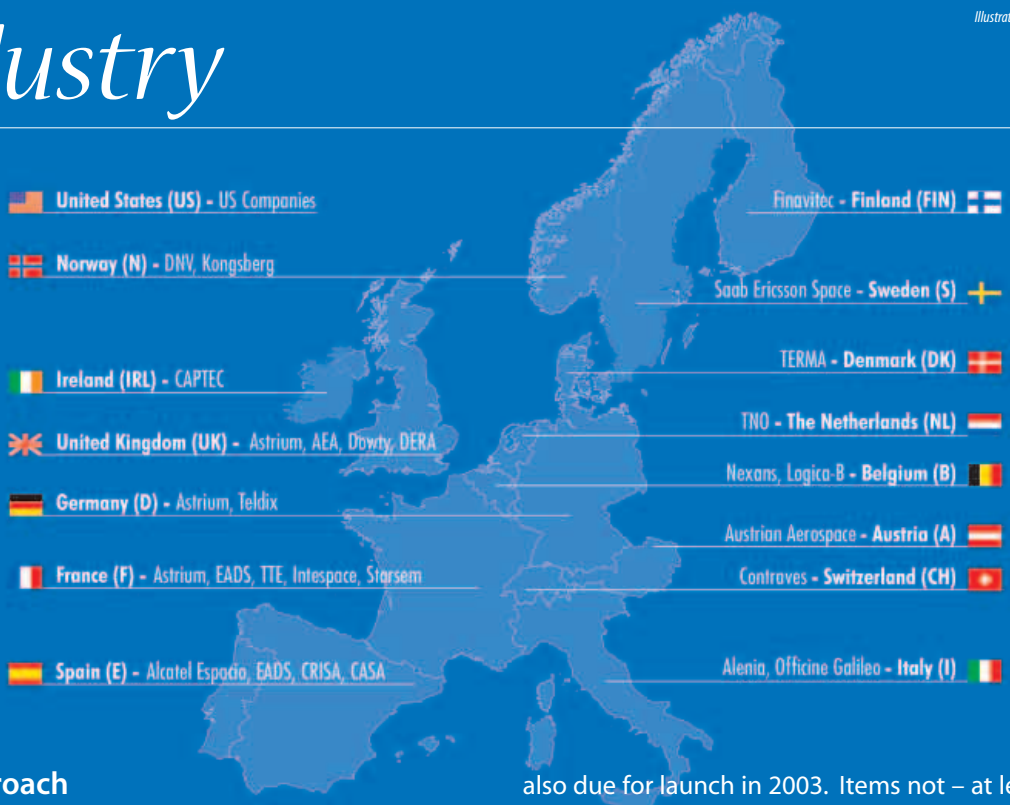
The Fregat will be ignited twice. The first ignition will put it into a circular orbit around the Earth after separation from Soyuz. The second, a few hours later, will inject Mars Express into its interplanetary flight trajectory.

Courtesy of Starsem

The Soyuz-Fregat rocket.

Launcher	Launcher Capability
Soyuz/Fregat:	1200 kg (incl. launcher adapter)
Spacecraft Item:	**Current Mass**
Dry spacecraft:	680 kg
Propellant:	428 kg
Lander:	60 kg
Payload:	113 kg
Total Launch Mass:	1108 kg

Industry


United States (US) - US Companies
Norway (N) - DNV, Kongsberg
Ireland (IRL) - CAPTEC
United Kingdom (UK) - Astrium, AEA, Dowty, DERA
Germany (D) - Astrium, Teldix
France (F) - Astrium, EADS, TTE, Intespace, Starsem
Spain (E) - Alcatel Espacio, EADS, CRISA, CASA
Finavitec - Finland (FIN)
Saab Ericsson Space - Sweden (S)
TERMA - Denmark (DK)
TNO - The Netherlands (NL)
Nexans, Logica-B - Belgium (B)
Austrian Aerospace - Austria (A)
Contraves - Switzerland (CH)
Alenia, Officine Galileo - Italy (I)

Map showing companies building the Mars Express Orbiter.

Illustration by Medialab, © ESA 2001

A new approach

Mars Express is a pioneer - and not just because it is Europe's first mission to the Red Planet. It is also pioneering more economic ways of building space science missions at ESA. These new working methods have already proved effective and will be applied to future science missions in the Agency's long-term scientific programme.

ESA is spending just 150 million Euros (1996 prices) on Mars Express, which is about one third of the cost of previous, similar missions. This sum will pay for the spacecraft, the launch and the operations: Orbiter instruments and the Beagle 2 lander are provided separately. Also, the mission is being built unusually quickly to meet a narrow launch window in May/June 2003.

Savings are being made by re-using existing hardware, adopting new project management practices, shortening the time from original concept to launch, and procuring the most cost-effective launcher available. *"What we are doing with Mars Express will affect flexible missions at the Agency, which may, in future, be linked more closely to major missions. We are making savings, but we are not taking big risks,"* says Rudi Schmidt, Mars Express Project Manager.

Mars Express is making maximum use of existing technology that is either 'off-the-shelf' or has already been developed for Rosetta, ESA's mission to a comet also due for launch in 2003. Items not – at least partly – in common with Rosetta constitute only about 35% of the spacecraft.

ESA is delegating tasks to Astrium Toulouse, France, the spacecraft prime contractor, that previously would have been done by the project team at ESTEC. In particular, Astrium is managing the technical interfaces between the spacecraft and science payload, and between the spacecraft and launcher. This shift in responsibility is allowing industry to streamline procedures and ESA to reduce the size of its project team to half that of previous equivalent projects. *"This new scheme is best suited to Mars Express constraints. Industry is more responsible in terms of the interfaces, which means we can have a more efficient decision-making process,"* says Vincent Poinsignon, Mars Express Project Manager at Astrium.

The time from concept to awarding the design and development contract was cut from about five years to little more than one year. Astrium won the prime contract in March 1999 in competition with two other consortia. The design and development phase will take under four years, compared with up to six years for previous similar missions.

The Soyuz/Fregat launcher matches the needs of Mars Express well and is thus able to offer the best available price/performance ratio.

Structure of the Mars Express spacecraft being built at Contraves (Switzerland).

Europe-wide involvement

"If you include the prime contractor, all the sub-contractors and the scientists and technicians working on instruments in research institutes, the Mars Express project is creating several hundred jobs throughout Europe," estimates Rudi Schmidt.

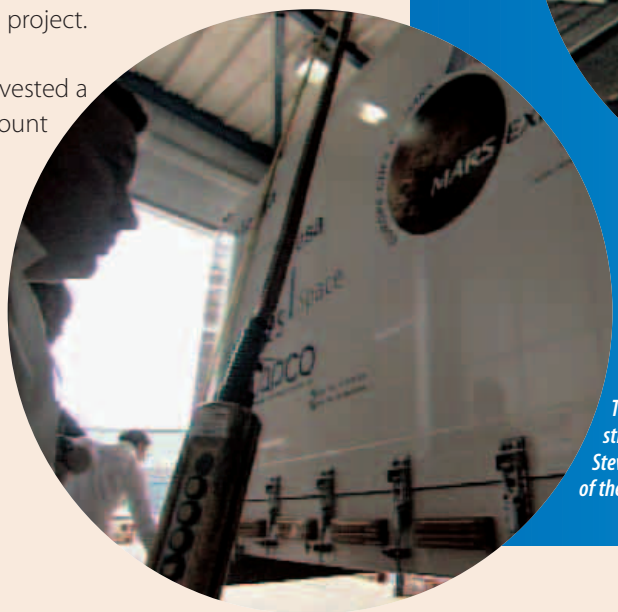
During 2001, the peak year for development, about 80 of these jobs are at the prime contractor, Astrium, in Toulouse. During 2002, as the workload shifts from design and development to system and payload integration and final testing, this number will decrease to about 30. The number working at Alenia (Turin, Italy), the sub-contractor in charge of the testing programme, will increase from about 15 to 30. There are many more industrial jobs at Astrium's sub-contractors, which include 24 companies in 15 European countries.

Beagle 2 is being built by a consortium of university teams and industrial partners, mainly in the UK. Astrium Stevenage (UK) is the prime contractor and Martin-Baker Aircraft is managing the entry, descent and landing system. Approximately 50 academic, scientific or industrial establishments have been or are involved in the project.

ESA has also invested a substantial amount of funds in the Beagle 2 Consortium.

The Mars Express electrical test bench at Astrium Toulouse (France).

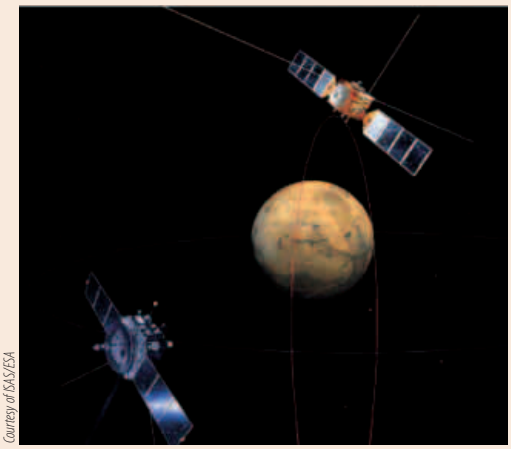
The Mars Express spacecraft arrives in the UK on route to Astrium Stevenage from Contraves (Switzerland).



The Mars Express spacecraft structure arriving at Astrium Stevenage (UK) for integration of the propulsion system.

International collaboration

Scientists and engineers from several countries outside Europe are participating in or contributing to Mars Express. Japan, Russia and the USA, however, have the greatest involvement.



Courtesy of ISAS/ESA

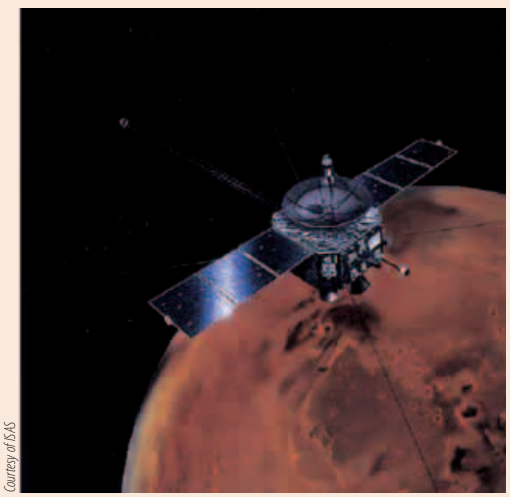
Nozomi, in equatorial orbit, and Mars Express, in polar orbit, around Mars.

Japan

The Japanese spacecraft Nozomi will go into near-equatorial orbit around Mars shortly after Mars Express enters polar orbit. Nozomi had been due to reach the Red Planet in October 1999, but was delayed by a problem with its propulsion system. The two missions are seizing the opportunity to do collaborative science.

Both share a common interest in the martian atmosphere. Nozomi is even carrying a close relative of ASPERA, the instrument on Mars Express to study interactions between the upper atmosphere and the solar wind.

Artist's impression of Nozomi in orbit around Mars.



Courtesy of ISAS

Measurements recorded simultaneously by both spacecraft from their different vantage points will provide an unprecedented opportunity to study such interactions. The two missions have agreed to a programme of joint investigations and to the exchange of Co-Investigators between the instrument teams.

United States

ESA's Beagle 2 will land on Mars at about the same time as NASA's Mars Rover mission. The two space agencies are making arrangements to use each other's orbiters as back-ups for relaying data and other communications from the landers to Earth. Mars Express is also intending to use NASA's Deep Space Network for communications with Earth during parts of the mission. US scientists are playing a major role in one of Mars Express payload instruments, MARSIS, and participate as Co-Investigators in most other instruments.

Russia

Five of the instruments on Mars Express (HRSC, OMEGA, PFS, ASPERA and SPICAM) are descendants of instruments originally built for the Russian Mars '96 mission. Each of the seven orbiter instrument teams on Mars Express has Russian Co-Investigators who contribute their intellectual expertise to the project.

A global effort to explore the Red Planet

Mars Express and Beagle 2 mark the beginning of a major European involvement in an international programme to explore Mars over the next two decades. Europe, the USA and Japan are planning to send missions, but many more countries will be contributing experiments, hardware and expertise. Each mission will make its own unique contribution towards a global effort coordinated by the International Mars Exploration Working Group (IMEWG).

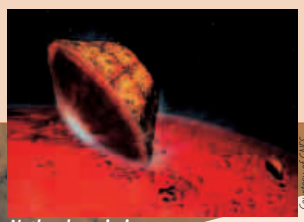
The idea for a European mission to Mars is not new. Before choosing Mars Express, ESA had debated and studied other mission ideas,

Previous ESA studies on missions to Mars.

including Intermarsnet, an orbiter and four landers to perform atmospheric, surface science and seismic studies from a network of widely-spaced locations on Mars. Intermarsnet was not selected on cost grounds, but the idea and preliminary studies are not going to waste. The French space agency CNES is planning to send four similar, though smaller and cheaper, Netlanders to Mars in 2007.

The table below summarises plans up to 2007, with plans up to 2003 being firm and subsequent ones still subject to alteration.

Date	Mission and agency	Spacecraft	Studies
1996	Mars Pathfinder, NASA	Lander	Surface imaging and chemical composition with European instruments
1996	Mars Global Surveyor, NASA	Orbiter	Imaging, topography, magnetic field and surface composition.
1998	Nozomi, ISAS (arrival in 2003)	Orbiter	Atmosphere and its interaction with the solar wind. Coordination with Mars Express
2001	Mars Odyssey, NASA	Orbiter	Surface composition.
2003	Mars Express, ESA	Orbiter	Surface, subsurface and atmosphere of Mars, in particular the search for water.
2003	Beagle 2, ESA	Lander	Exobiology, geochemistry and surface–atmosphere interactions.
2003	Mars Rovers, NASA	Rover	Robotic explorers able to track 100 m/day. Geology and search for water.
2005	Mars Reconnaissance Orbiter, NASA	Orbiter	Atmosphere and detailed imaging to identify potential landing sites.
2007	Orbiter plus four Netlanders, CNES	Orbiter	Remote-sensing experiments plus telecommunications between the Netlanders and Earth.
		Landers	Atmosphere, internal structure and geology of landing sites.



Netlander mission

Courtesy of CNES

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